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In This Issue:

- Leadership in Uncertain Times
- Why MORS Matters
- Climate Change and National Security Analysis

Guiding Our Nation Through Uncertain Times

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A Strong Foundation for Uncertain Times

The guiding principle for our Society's activities this last year has been, "Building the Future on a Strong Foundation." The theme for this year's Symposium is "Guiding the Nation through Uncertain Times." We chose these complimentary themes with the understanding that in times of great uncertainty, it is best to build upon first principles. The strong foundation of MORS includes our constituent members, our vital national security analysis mission, and the need to provide professional development services to our members to better accomplish that important mission. Because of this you will see a larger continuing education offering at this year's Symposium than at any in recent memory. Because of this, we have explored new methods of delivering services; for example the all-virtual skills workshop on test and analysis methods that offered nearly 100 hours of online instruction. Because of this we added a new classified and peer-reviewed journal in which our members can publish important work. And because of this we expanded our student webinars and recently conducted a very inspired and multifaceted education and professional development colloquium. Although we have had hard resource-driven choices to make at every step along the way, we continue to provide and improve the most important services the Society has to offer and thereby build a stronger future for our members and our nation.

82nd MORS Symposium

As this issue rolls off the press, the 82nd MORS Symposium is just a few short weeks away. At the heart of our annual gathering are the hundreds of great presentations, given in a variety of working group and classification settings by our lifelong professional friends and colleagues. Not only do we all grow richer from the experience, the presenters also further refine their technical skills and receive important feedback on their projects from peers. Thus our work, our skills, and our profession are strengthened tremendously through this extraordinarily dynamic four days of OR collaboration and learning.

In keeping with the themes described above, we are excited to offer a wide variety of educational and tutorial programs at this year's Symposium. Of particular interest are two trailblazing CEU Short Courses developed by the Air Force Institute of Technology's Dr. Darryl Ahner and MORS Past President Mike Garrambone that provide a

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fundamental understanding of how to participate in and lead studies at national defense analytical agencies. "Introduction to Analysis for Practitioners," and "Introduction to Analysis for Study Leaders" are applied courses and contain lessons not normally taught in civilian or service schools. They help prepare analysts to serve as productive members of a study team, or to lead that study team in the case of the study leader's course. Classes include "how to" instruction on defining the problem, developing study objectives, developing and using measures of merit, acquiring and cleaning data, developing scenarios, employing assumptions, honing OR presentation techniques, and presenting analysis to leaders. These courses are structured to provide a Continuing Education Unit (CEU) to those who register for and participate in all 10 hours of instruction for either course.

As the name implies, the practitioner's course is designed for junior analysts who have just joined an analytic organization or who have not yet had projects to expose them to the fundamentals of analytical studies. This course is taught by senior analysts who have tremendous experience in conducting military and civilian studies. All lessons have strong academic underpinnings, but the material centers on what young analysts should know and do in conducting studies. A student will finish this course with a greater understanding of the application knowledge and technical skills that will make them much better in performing analyses.

The study leaders' course is designed for analysts with three to 10 years of experience who are headed for study leadership positions within their organization. It covers the skill sets and project planning knowledge essential for leading technical studies, including leader responsibility, composition and duties of the analytical team, importance of strong problem definition, use of measures of merit, study planning, and presentation techniques. All lessons use real-world examples to focus students on what leaders should know and do when conducting studies and thereby return to their organizations as better study leaders. Be sure to check out these courses and all of the great educational offerings at the Symposium.

Industrial Partnership

The constituency of MORS is an amalgam of government, industry, and academia, with many members serving in different capacities over their careers. Over the past two years, MORS has made a committed effort to strengthen government-industry relationships through better partnerships with industry. Two visible components of this effort are the Industry & Institution Partnership (IIP) Program and the annual Industry Showcase. In addition to the opportunities for enhanced interaction with MORS and our members, the MORS IIP Program offers memberships, symposium discounts, advertising, and online job postings. We thank our early partners for making this program successful: Platinum Partners Lockheed Martin and WBB; Gold Partners EM Solutions, SAS, and InfoSciTex; Silver Partner Argonne National Lab; and Bronze Partners TAG, DCS Corp, and Cana Advisors.

The annual MORS Industry Showcase was held on March 13 in Crystal City with the goal of strengthening government-industry relations. This unique event featured expert speakers and discussion panelists from both government and industry who addressed this year's theme: "Big Data" challenges and opportunities in the national security environment. We thank all those who participated, and especially our three plenary speakers for their stimulating presentations: Dr. W. Forrest Crain, Director of the Army's Center for Army Analysis; Mr. Bryan Harris, Director of Research and Development for Cyber Analytics at SAS; and Mr. David Markham, Vice President for Advanced Programs at Lockheed Martin Space Systems. For a full list of panel participants, be sure to see the article on page 14. Thanks also to Industry Relations Committee Chair Dennis Baer, FS, and MORS Director of Industry and Institutional Relations, Jennifer Ferat, whose tireless efforts not

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only made the event possible, but because bad weather in December forced us to postpone until March, had to be undertaken twice!

Strong Foundation, Changing Leadership

I thank the members of the Executive Council for their outstanding work this year: Immediate Past President Mike Garrambone; President-Elect Rafael Matos; Vice-President for Finance and Management Donna Blake; Vice-President for Meeting Operations Tom Denesia; Vice-President for Member and Society Services Julie Seton; and Secretaries of the Society Bob Koury and Touggy Orgeron. I also want to recognize four Advisory Directors who took on key leadership roles this year: Kirk Michealson, FS, and Trena Lilly served as cochairs of the Continuing Education Committee and have brilliantly established a base for our future education and certification needs; Dennis Baer, FS, led the Industry Relations Committee as mentioned earlier; and Simon Goerger served as chair of the Virtual Operations committee and significantly helped move the Society forward in all things virtual. I thank the rest of the MORS Board of Directors, the Fellows of the Society, our Sponsors and their representatives, and our publication editors, all too numerous to call out by name, for the extraordinary work and assistance under difficult circumstances. Finally, our small professional staff this year has been phenomenal! Where MORS has traditionally has an office workforce of five full-time employees, CEO Susan Reardon and Director of Member Services Liz Marriott have very skilfully covered the bases to provide the many services we offer and to keep the engine of MORS running.

It has been an honor to preside over and care for the Society this past year. The spirit of MORS is incredible. To paraphrase Joe Theismann, if we could bottle the spirit of MORS, we could analyze the world! I wish the absolute best for incoming President Rafael Matos during this next year. And I look forward to seeing everyone at the Symposium

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MAS PRESIDENT

MAS President's Comments

Although we are unable to host our annual Spring MAS Conference this year because of Department of Defense travel and budgetary restrictions, several other conferences are scheduled throughout 2014 if one can obtain funding and authorization to attend.

The 82nd MORS conference will be held June 16–19 at the Hilton Mark Center in Alexandria, Virginia. That is good news for all. There are several opportunities throughout the year to participate in venues at regional, national, and international levels. Please contact us if you wish to participate in program development, chair a session, and/or present your work. Details are on the INFORMS and MAS community websites, but here is a quick summary:

- 2014 INFORMS Big Data: June 22–24, 2014; San Jose Convention Center and Marriott San Jose, San Jose, California
- IFORS 2014 Triennial Conference: July 13–18, 2014; Barcelona, Spain
- INFORMS Annual Meeting 2014 San Francisco: November 9–12, 2014; Hilton San Francisco

Initiatives

We continue to pursue several MAS initiatives. Let us know if you would like to contribute to any of these, or perhaps initiate your own.

Our MAS/MORS initiatives, led by Walt DeGrange, include "joint" student membership and a continuing student webinar program. Walt noted that the November and January MORS/MAS Joint Student bimonthly webinars were very successful. The webinars are currently under the watchful eye of MORS, which is off and running with the program.

The next webinar, "Five (5) Questions about Your Simulation Model," presented by CAPT Jeff Hyink, USN, will be held April 18, 2014, 1200–1300 ET. Please consult the webinar website (www.mors.org/events/studentwebinars.aspx) for more information and the latest on webinars. The webinars are free but space is limited so sign up early.

Awards

Annually, MAS sponsors and presents several awards that align with our society goals. These awards, presented at the annual INFORMS conference, cover three general categories representing future potential, recent achievement, and long-term contributions to military operations research. In addition to recognizing top operations research undergraduate students from each of the Service academies, the Seth Bonder Scholarship, which includes a $4,000 grant, is awarded to a promising young doctoral researcher. The Koopman Prize, a $500 award for the best recently published paper or report on military operations research, honors the memory of Bernard O. Koopman (1900–1981), one of our early pioneers in operations research. And the prestigious J. Steinhardt Prize, sponsored by the Center for Naval Analyses (CNA), is awarded for outstanding contributions to military operations research for lifetime achievement rather than for a specific contribution. See the article on page 24 for further details.

For details on each of these, click the "Awards" button on our website (www.informs.org/Community/MAS). Our awards committee coordinator, MAS Past-President Greg Parlier, is currently soliciting nominations, so please give consideration to potentially deserving colleagues you may know. You may also forward your nominations to me (wpfox@nps.edu).

Finally, I would like to ask for MAS members to consider submitting articles to *Phalanx*.

Affordability Analysis: Developing the Process

Kirk Michealson, FS, Special Meeting Chair, kirk.michealson@gmail.com

Affordability has been defined, but there is no consistent definition for affordability analysis across the Department of Defense. An effort is needed to develop and formalize affordability analysis processes, including recognizing the difference between cost and affordability analyses, and that affordability analysis should include mission-based, portfolio-based, and capability-based analyses. To address this need, MORS led a workshop, "Affordability Analysis: How Do We Do It?" in October 2012.[a] The recommended next steps from this workshop were:

- Form a team to continue working
- Complete the research not conducted during the three-day workshop
- Develop an affordability analysis "how to" manual/guidebook/process (for simplicity, based on the March 2014 Workshop, referred to hereafter as "thought roadmap")
- Pilot the thought roadmap on a couple of projects

To continue these next steps, MORS established an Affordability Analysis (AA) Community of Practice (CoP) in February 2013. The AA CoP recently completed researching the recommended items from the workshop in its Affordability Research Document (ARD), which addresses the first two next steps. The status of the AA CoP is posted on the MORS Affordability Analysis CoP webpage: http://www.mors.org/events/affordability-analysis.aspx.

Participants in the October 2012 Affordability Analysis Workshop and the AA CoP come from both government and industry. The Assistant Secretary of Defense for Acquisition; the Office of the Secretary of Defense (OSD) for Acquisition, Technology, and Logistics; and the Joint Staff/J8 are the proponents. Additionally, several professional organizations—the National

Defense Industrial Association Systems Engineering (NDIA SE) Division, the International Council for Systems Engineering (INCOSE), and the International Cost and Estimation Analysis Association (ICEAA)—have joined with MORS to plan, contribute, and conduct the workshop and CoP.

The next step from the October 2012 AA Workshop is for the CoP to develop an Affordability Analysis "how to" manual, guidebook, or process. Thus, the goal of the "Affordability Analysis: Developing the Process" AA CoP meeting, starting with information from the AA Workshop and CoP, especially the affordability analysis framework in the ARD, is to use a Lean Six Sigma (LSS) Value Stream Mapping (VSM) approach to develop a foundation for the thought roadmap.

Goals and Objectives

The overall goal of the AA CoP is not to develop a prescriptive "one-size-fits-all" document or a manual on doing optimal resource allocations, but to develop an affordability analysis process with best practices, lessons learned, considerations, and so on. Secondary goals include:

- To ensure that programs are in the right context of the larger picture of mission needs, capabilities, and opportunity costs;
- To communicate about boundaries that help determine what is doable/affordable because there is no way to connect the various versions of the truth; and
- To include not only lessons learned to determine whether the portfolio is affordable, but also to include whether the missions financed were successful and solvent.

The AA "how to" process will most likely be a thought roadmap that allows the DoD at many institutional levels to have a data-based conversation about affordability and affordability analysis using ground truth boundaries from adjacent layers that serve as defining assumptions about the fiscal limits and mission needs on the tradespace in the layer in question. Additionally, the "how to" thought roadmap is important to government and industry because it should support the following tasks that are not done well today:

- Scoping mission or capability improvement goals and getting to the crux of what will determine affordability quickly;
- Articulation of affordability constraints, with acquired/estimated parametric understanding of impacts;
- Data synthesis with more complete clarity of cost versus value issues that are challenged by data and process transparency;
- Risk awareness, opportunity cost visibility, and better visibility of calculated risks;
- Cost-conscious Course of Action (CoA) and alternative development;
- Visualization of affordability value propositions within affected portfolios (is it really affordable?);
- Preservation of cutback rationale(s);
- Early recognition of key affordability issues (i.e., we can no longer start programs that we can't finish); and
- Cross-service capability trades can be understood and made to preserve operational value and be more affordable, instead of top-level trades made (lowering TOAs) that may be implemented in ways that severely decrement operational value.

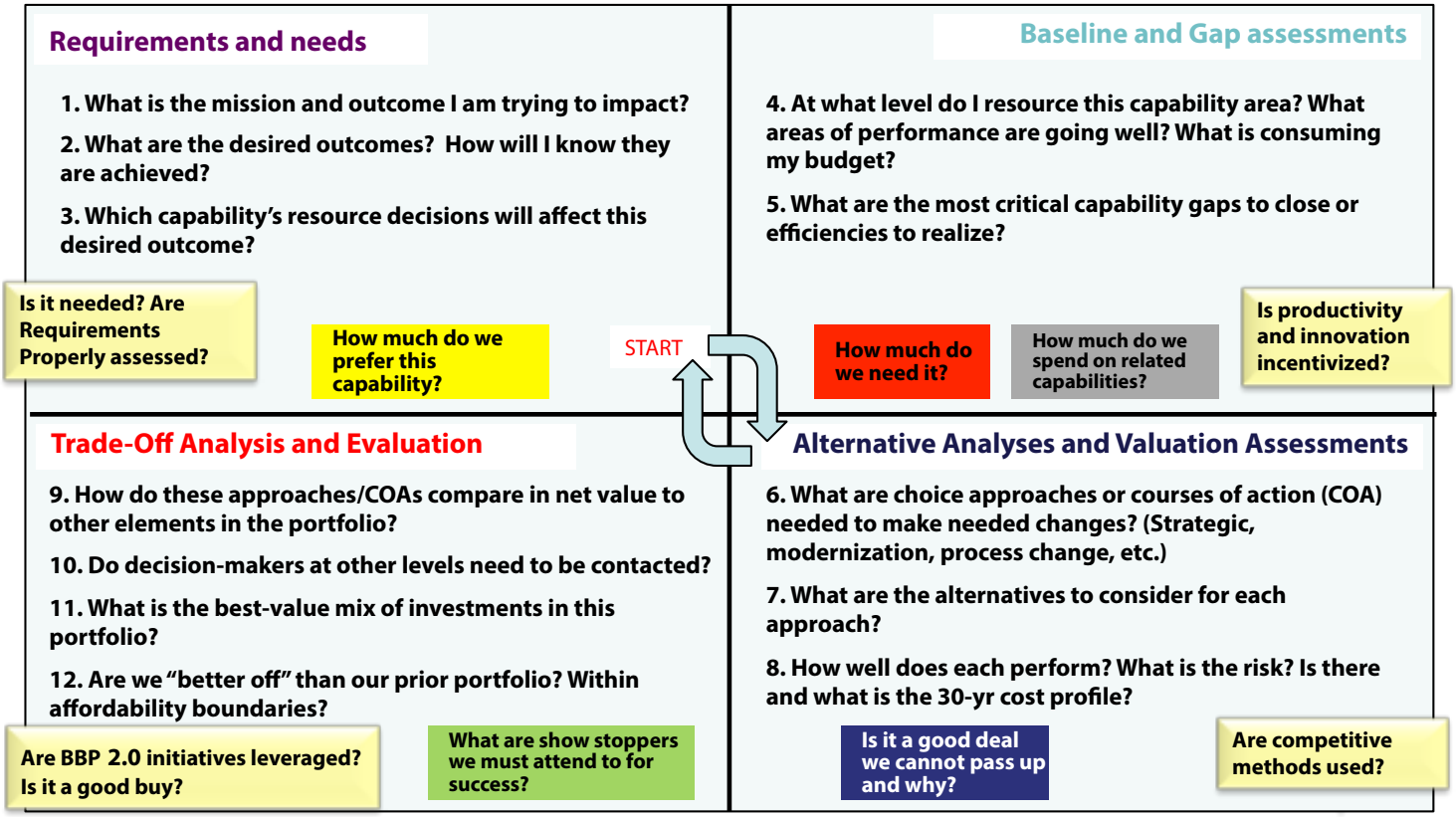
The result of the AA CoP meeting was a foundation for the thought roadmap; however, in a little over two days of work, it was not intended to be the complete roadmap. Developing this foundation will, among other things, focus the AA CoP on the substantive areas needing the most attention to fully define the process in subsequent effort.

MORS Firsts

Because the October 2012 "Affordability Analysis: How Do You Do It!" workshop was the first time for MORS to work with partnering professional organizations, there were also a couple of firsts for MORS with the "Affordability Analysis: Developing the Process" workshop.

This was the first time that a MORS workshop recommended a MORS CoP and then that CoP hosted a MORS Special Meeting, ensuring that the associated MORS Symposium composite group and working groups (CG E: Acquisition, WG 26: Cost Analysis, and WG 27: Decision Analysis) are kept informed. The AA CoP (www.mors.org/events/affordability-analysis.aspx) was formed in February 2013. After completing the research from the meeting (the second next step from the workshop), the AA CoP planned and conducted the March 2014 MORS meeting, "Affordability Analysis: Developing the Process" (www.mors.org/events/aa-developing-the-process.aspx).

Figure 1. Affordability analysis framework: The affordability analysis process includes four phases with 12 driving and "vital" questions.



This was also not the typical MORS workshop or minisymposium with briefings and limited discussions. The attendees were asked to come prepared by being familiar with the October 2012 AA workshop's final report and the AA CoP's ARD. There were no keynote presentations and just a few background briefs to prepare the participants, and most of the time was spent in working sessions.

Finally, this was the first time MORS hosted a LSS event using LSS facilitators, tools, and techniques to collect the underpinnings/foundation necessary for the thought roadmap.

Workshop Description

During the background plenary session on Monday afternoon, March 10, after welcomes by MORS President Dr. Steve Riese, and the MORS AA CoP Chair, Kirk Michealson FS, three background briefs were presented as review for the meeting participants:

- Highlights from the October 2012 MORS AA workshop from Workshop Chair Kirk Michealson, FS;
- An update from OSD on the current affordability policy by Dr. Chad Ohlandt; and
- An overview of the AA CoP's ARD (www.mors.org/UserFiles/file/2013-Affordability-Analysis/Affordabilty_Analysis_Research%20_%20v%2023_2014-01-27.pdf) from the AA CoP's core team lead, Dr. Lisa Oakley-Bogdewic.

The AA CoP meeting chair, Kirk Michealson, FS, then gave an overview of the meeting and the LSS VSM that was used during the meeting.

Section 4.3 of the ARD describes an affordability analysis framework with 12 questions in four phases (see Figure 1). For this MORS AA CoP meeting, a working group was assigned to each phase with a synthesis group responsible for ensuring that the necessary information is included across all phases. After the meeting and VSM overview, the meeting participants broke into assigned working groups for introductions and a more detailed overview of their working group's assigned phase from their working group chair (the working group chairs were members of the AA CoP core team that coordinated the development of the ARD):

- WG 1: Requirements and Needs; Dr. Lisa Oakley-Bogdewic, MITRE
- WG 2: Baseline and Gap Assessments; Rick Null, Lockheed Martin Aeronautics
- WG 3: Trade-Off Analysis and Evaluation; Steve Notarnicola, Lockheed Martin Center for Innovation

- WG 4: Alternative Analysis and Valuation Assessments; Bob Koury, Price Systems

On Tuesday and Wednesday, March 11 and 12, each working group collected data using LSS VSM facilitators, tools, and techniques for all the questions in each phase of the affordability analysis framework (Figure 1) to answer the same six subquestions for each main question:

- What are the driving questions?
- What are the data or inputs needed?
- What are the decisions supported?
- What are the processes necessary to complete this step?
- What are the exit criteria for sufficiency?
- What are the exit criteria for quality?

Lean Six Sigma Event

To obtain as much information as possible in a little over one and a half days. The workshop was facilitated by trained LSS Black Belts and LSS Green Belts from Lean 6 Consulting and the site host, Lockheed Martin (LM):

- LSS Black Belts: Greg Kerchner, President Lean 6 Consulting; Kirk Michealson, FS, Lean 6 Consulting; Russ Riva, Lean 6 Consulting; and Greg Niemann, LM Corporate Engineering
- LSS Green Belts: Marilyn Pineda, LM Corporate Engineering; Will Pijai, LM Net-Centric Integration & Demonstration (NCID); Chris Eastman, LM NCID; and Heather Cisler, LM Missiles & Fire Control

Many LSS organizations teach VSM events slightly differently. This MORS AA CoP meeting used a "modified" five-step VSM:

1. Define the boundaries
2. Define the value
3. Define the outcome
4. Map the value stream
5. Develop the get-to-excellence plan

Definition: A Lean Six Sigma Value Stream transforms information into a final product/service for delivery to the customer. The value stream is all activities that provide value or are required, but doesn't include the non-value-added activities. The goal of a LSS VSM event is to identify these value-added and required activities and then map these activities into an organized process.

Steps 1–3 were inputs to the event based on the research in the AA CoP's ARD, whereas steps 4–5 were completed during the meeting.

These steps, essential elements of this modified LSS Value Stream Mapping process, are described in the accompanying article, "The MORS AA CoP LSS VSM Process"

Meeting Preliminary Insights

The meeting objectives were exceeded in each working group. The goals were to collect affordability analysis-related information as a foundation to build an eventual "how to" guidebook or thought roadmap. The working groups started by discussing background questions for their phase (i.e., driving questions, data or inputs needed, decisions supported, process necessary, and exit criteria for sufficiency and quality).

Using that information, the working groups developed draft activity considerations in a process map for their phase, and discussed the inputs needed and outputs generated. After each other phases' inputs and outputs were reviewed, the activity process maps were updated. Finally, each working group developed its Get-to-Excellence Plan with recommended actions for the AA CoP after the meeting.

Using that foundation, a draft affordability analysis process was created several weeks later, and at the time of this article, the thought roadmap was reviewed by the AA CoP and is being reviewed by the attendees of both October 2012 and March 2014 Affordability Analysis MORS Workshops.

Initial Highlights from the Affordability Phases

Phase 1: Requirements and Needs

This phase is a stage-setting phase. It generates critical assumptions and shapes the scope of affordability analyses. It serves to identify analyses needed, as well as the appropriate trade space to assess. Overall, this phase of the affordability analysis should be able to affirm that the requirements of the scope have been properly assessed, and the capabilities in question are still needed.

The first step is to understand the mission and outcome (capability) that is being impacted by creating a description of the mission and task successes. Next, the desired outcomes are determined through discussions with stakeholders to determine criteria and qualitative value propositions. Finally, the capability resource decisions are discussed to determine which are feasible, sufficient, and of quality.

The working group also established some initial assumptions for the process:

- It is for the components with acquisition or spending authority.
- It can be tailored for each component.
- It can be iterative instead of sequential.

Phase 2: Baseline and Gap Assessments

During this phase, the main activities are to:

- Establish and iteratively maintain baseline effectiveness and cost;
- Identify and prioritize gaps, efficiencies, and incentives in costs and performance; and
- Prioritize gaps, efficiencies, and incentives.

Some initial comments from the working group were:

- Inputs and outputs can be tailored to meet analysis and decision-maker needs.
- New DoD 5000.02 requires updates at major milestones and significant budgetary actions.
- The Affordability Analysis Guide should have a "Quick Start" section and appendices with examples / use cases.
- Affordability analysis must include consideration for uncertainty.

Phase 3: Alternative Analyses and Valuation Assessments

The goals of the third phase are to select CoAs/strategies, determine the initial alternatives to meet the required missions and capabilities, and perform initial screening by conducting some basic performance/operational benefit, cost, and risk analyses to ensure that there are feasible alternatives for the follow-on tradeoff analysis.

Phase 4: Trade-Off Analysis and Evaluation

To conduct thorough tradeoff analysis, the working group developed five activity process maps:

- Prepare for analysis,
- Solicit/determine value structure,
- Conduct tradeoff analysis,
- Perform sensitivity and risk analysis, and
- Commit decision.

  The ultimate goal of this phase and the overall process is to provide a set of investment portfolios including accompanying assessments such that the decision makers can apply their own expert judgment to the choices.

During the working group discussions, the following overall basic characteristics of credible and useful affordability analysis were developed:

- Defined methodology
- Incorporates sufficient subject matter expertise (SMEs)
- Incorporates input from relevant stakeholders
- Clear purpose of tradeoff analysis (clarity on decision to be made)
- Defined scope
- Documented constraints and assumptions
- Incorporates risk and sensitivity analysis
- Credible/authoritative data

The MORS AA CoP LSS VSM Process

As noted in the workshop report, the MORS Affordability Analysis Community of Practice (AA CoP) used a modified five-step LSS Value Stream Mapping process. This article is an overview of this modified process specific to the March 2014 MORS "Affordability Analysis: Developing the Process" Workshop. Steps 1-3 were developed from the AA CoP's "Affordability Research Document" and used as an input to the workshop, while steps 4-5 were the primary focus of the workshop.

For *Step 1: Define the Boundaries,* high-level overall inputs to phase 1 and high-level overall desired outputs for phase 4 were developed from the Affordability Research Document (ARD). The general overall inputs were:

- Missions to be performed or barriers to overcome;
- Mission objectives and outcomes (the targets may or may not be "given," the affordability analysis activity can derive these);
- Mission measures of success (also may be given or derivable); and
- Current resources to execute the mission and capability structure in the baseline to align to outcomes.

Participants focused on a generalized mission/process, not a specific mission/program during their discussions. Also, more defined input/output charts were developed for each phase during the meeting.

General outputs were the need for cross-portfolio interaction as well as analysis of alternatives or courses of action (CoAs) fulfilling mission needs, which include:

- Comprehensive range of alternatives considered (including baseline)
- Expected net present value for alternatives (marginal value)
- Continuity of the trade study analysis itself so if necessary it can be redone without starting over

Next Steps

After the "Affordability Analysis: Developing the Process" meeting, AA CoP Chair Kirk Michealson, FS, collected all the information (i.e., outbriefs, butcher paper sheets, stickies, and other notes) to develop this article, the results brief for the NDIA SE Division April Meeting, INCOSE, and the 82nd MORSS, and the draft affordability analysis "how to" thought roadmap. The AA CoP will work on the recommended actions, as well as study and update the document in staged reviews. When consensus is reached on the thought roadmap, the AA CoP chair will coordinate with the CoP proponents and service representatives for potential projects to pilot the roadmap.

If you are interested in joining the MORS AA CoP and helping develop the government/industry affordability analysis "how to" thought roadmap, please review the MORS AA CoP webpage (www.mors.org/events/affordability-analysis.aspx) for meeting dates, times, and telecom number, or contact AA CoP Chair Kirk Michealson, FS, at kirk.michealson@1979.usna.com.

- Effectiveness levels: Outcomes achieved, capability gaps closed
- Investment levels: POM aggregates and 30-year cost profiles for capabilities
- Risk levels: Needs that were not selected in tradeoff analysis, or areas used to "pay bills"
- Implementation schedules: Clearly manage expectations of when capabilities will be delivered

For *Step 2: Define the Value,* the initial value statement was, "Affordability analyses will change the leadership conversation and use data-driven assessments to make hard choices more fiscally feasible and mission-relevant." Then for *Step 3: Define the Outcome,* the following overall objective was developed, "To provide the first-ever government/industry affordability analysis manual/guidebook/process" with the following goals:

- Practically, affordability analysis must substantiate a resource plan that is within a rationalized mission and budget scope, and makes measurable and sustainable trades between performance, innovation/progress, and cost effectiveness.
- Culturally, rewarding the practice and use of affordability analyses should change the discussion of decisions makers, enabling them to deliver portfolio outcomes that are more effective and efficient, staying within and informing budget boundaries and meeting mission requirements.

Then, to complete the VSM process (Steps 4–5) during the meeting, the six subquestions (listed in the "Lean Six Sigma Event" section of the workshop report) for each phase's main questions were answered with the LSS Black Belts and Green Belts using the following LSS VSM tools and techniques: brainstorming, process mapping (developing the foundation for the first affordability analysis process), SIPOC (supplier-input-process-output-customer) charts, get-to-excellence (action) plans, and PICK (possible-implement-challenging-kill) charts to prioritize recommended future actions.

Brainstorming

Brainstorming is a group or individual creativity technique during which efforts are made to find a conclusion for a specific problem by gathering a list of ideas spontaneously contributed by its member(s). General rules include:

- No premature decisions or evaluations
- "Wild" or "bad" ideas are welcome
- Don't sit on ideas; express them
- Quantity over quality
- Piggyback on the ideas of others

Process Mapping

Process mapping refers to activities involved in defining what an entity does, who is responsible, to what standard a process should be completed, and how the suc-

Note:

[a] The final report and other information from the October 2012 AA workshop are posted on the MORS Affordability Analysis Workshop webpage at http://www.mors.org/events/2012aa.aspx.

cess of a process can be determined. The main purpose behind process mapping is to assist organizations in becoming more efficient. A clear and detailed process map or diagram allows outside firms to come in and look at whether or not improvements can be made to the current process. Process mapping takes a specific objective and helps measure and compare that objective alongside the entire organization's objectives to make sure that all processes are aligned with the organization's values and capabilities.

SIPOC Chart

Suppliers and inputs, as well as outputs and customers are determined when developing SIPOC charts (Figure A). Working groups will create a SIPOC chart for their phases, comparing their inputs to the previous phase outputs and comparing their outputs to the following phase inputs.

Get-to-Excellence Plan

An action plan for completing the actions from the LSS VSM event that includes the actions, responsible people, due dates, and status.

PICK Chart

A PICK chart (Figure B) assists in prioritization by assessing each action with respect to ease of implementation (hard vs. easy) and payoff (small vs. big) on a two-dimensional chart:

- Possible: upper left quadrant (easy implementation, small payoff)
- Implement: upper right quadrant (easy implementation, big payoff)
- Challenging: lower right quadrant (hard implementation, big payoff)
- Kill: lower left quadrant (hard implementation, small pay off)

How possible, how implementable, how challenging, and how hard the recommended action item is depends on the working group's placement on the PICK Chart.

Figure A. Lean Six Sigma SIPOC chart.

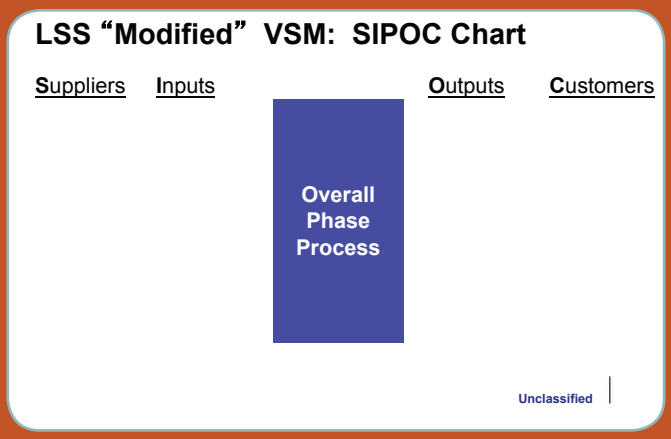
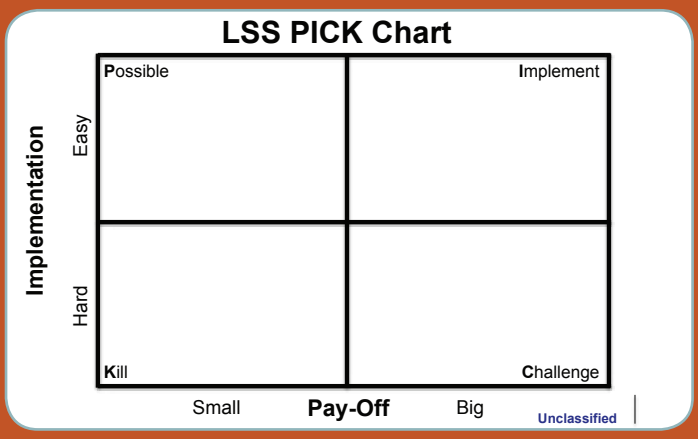


Figure B. Lean Six Sigma PICK chart



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Industry Showcase

Jennifer Ferat, MORS, jennifer@mors.org

The Military Operations Research Society (MORS) hosted the 2nd Annual Industry Showcase March 13, 2014 at the Crystal City Hilton. This year's showcase focused on the theme of "Building Government and Industry Relations to Advance the Practice of Operations Research in National Security." The event included addresses from Dr. Forrest Crain, Director, Center for Army Analysis; Mr. Bryan Harris, Director of Research and Development for Cyber Analytics at SAS; and Mr. Dave Markham, Vice President for Advanced Programs, Lockheed Martin Space Systems. In addition, there were panel discussions on how the government and industry collect and process information, effectively present it to leadership, and produce actionable decisions. Dr. Rafael Matos (MORS President-Elect) was the panel moderator for both the morning and afternoon panels. Panel members included: Dr. Tom Allen (the Joint Staff), Mr. Dave Jakubek (Office of the Secretary of Defense), Mr. Eric Hansen (SAS), Mr. Jim Muccio (US Air Force), and Mr. Mike Perez and Mr. Al Moseley (both from Whitney, Bradley, and Brown). Each of the keynote addresses and panel discussions ended with insightful questions from the attendees.

Mr. Harris kicked off the event by covering three key areas: observe, orient, decide, and act (OODA) loops. The concept, first applied to combat operations, is that decision making occurs in a recurring cycle of "observe, orient, decide, and act." In the context of business and Big Data, he discussed how to start small but think big with analytics, and articulated the increasing need to move beyond data visualization and toward data-driven narratives. He also

showed an entertaining video from George Carlin on where to store "stuff" as an analogy to data.

Mr. Harris' presentation was followed by three morning panelists, who discussed "Data to Information." Mr. Hansen briefly discussed how the role of the Department of Defense analyst may be changing. "Big Data Fatigue" and how several groups within DoD are working Big Data was the center of a discussion by Mr. Jakubek. Mr. Perez talked about the presentation of data to the leaders, about how the "Minority Report" model may be where analytics is going, and use of the agile process.

The topic for our featured speaker, Mr. Dave Markham, was "Building Analytic Partnership." He covered the current environment, sustaining operations research (OR) at Lockheed Martin, how to work across portfolios, and opportunities to partner with the various agencies.

In the afternoon, keynote speaker Dr. Forrest Crain presented the opportunities and challenges of government to industry OR, discussed "Army OR: Warts and All," and thoughts on the DoD "Big 3"—CAA, TRADOC Analysis Center (TRAC), and Army Materiel Systems Analysis Activity (AMSAA). He also presented four nominations for significant contributions to the science by renowned ORSA analysts, which were voted on at the end of his presentation.

Our second group of panelists discussed the progression of information to actionable decisions. Mr. Muccio discussed the use of Big Data in personnel; Planning, Programming, and Budgeting System (PPBS); lifecycle logistics; and all phases of war fighting. He also concluded with several key thoughts:

- There is no substitute for good analysis.
- Big Data analytics is just another tool.
- Visualization helps with Big Data.
- Analysts still tell the story.

Mr. Moseley discussed how tools have allowed analysts to focus on thinking about the problem and allows drill down, while briefing decision makers. Dr. Allen provided two short stories of how data affected the lives of retired and active duty personnel.

In addition to our speakers and panelists, exhibitors from EMSolutions, Infoscitex (a DCS company), Lockheed Martin, SAS, the Ranger Group, and WBB were in attendance. Releasable keynote slides by the speakers will be posted on the MORS website at http://www.mors.org/events/industryshowcaseandpdw.aspx. We are planning to hold the 3rd annual MORS Industry Showcase in December 2014 in the Washington, DC area. Please stay tuned to the MORS website for further detail

President-Elect Platform Statement

Operations Research: National Security Analysis for 21st Century

Tom Denesia, Technical Director, NORAD-USNORTHCOM Analysis Division; MORS Vice President of Meeting Operations; thomas.denesia@northcom.mil

I am excited to have the opportunity to be your President and look forward to the challenges we face in this difficult fiscal environment. Following Dr. Steve Riese and Dr. Rafael Matos will not be an easy task, but my intent is to mature many of their initiatives, including targeted special meetings and professional development, within our current budget constraints. To support this, I will emphasize virtual interactions at all levels, push to have more short courses and continuing education opportunities, and focus special meetings on key senior leader topics.

We have the means to accomplish this through some of our traditional structures, but to address the budget realities, MORS must adapt to a more virtual environment. Many of us have already started operating in this fashion, and I intend to push the boundaries of virtual interactions across all aspects of the Society (symposia, education colloquia, special meetings, continuing education, and mentoring). Every meeting and gathering, including regional chapters, should have a virtual aspect to accommodate those who would like to attend but are unable to do so in person. We have a great deal of talent within our membership and I ask each of you to step up with your thoughts, your ideas, and your time to help our Society continue to remain the premier operations research (OR) organization in the United States.

Throughout my career, I have worked to provide actionable analyses to my leadership and to share that work with the MORS community, which I have been honored to be part of for the last three decades. Over the years, I have participated in the tremendous growth and progress of our Society, by briefing and leading a number of working groups (WGs), composite groups (CGs), special meetings, and society meeting operations. These experiences have shaped my views and reinforced the reality of continuous change that we all are dealing with in our careers. We must be flexible and provide timely quantitative assessments for the most pressing defense issues.

My experiences from the Space WG to the Transportation and the Intelligence WGs have given me a background of flexibility and responsiveness to our senior leadership in addressing ever-changing national security questions. For example, when the Secretary of Defense stood up USNORTHCOM, I was engaged in defining new measures of effectiveness (MOEs) to articulate our mission and quantify our ability to perform these new missions. We were pushed to the limit, with a compressed timeline, to develop a number of

nontraditional measures capturing the essence of homeland defense. These have evolved, but current MOEs still retain the core measures that were developed in 2003.Within the MORS community, I recommended to the Board that a new working group be established to reflect both the homeland defense and homeland security equities and to accommodate our new DHS sponsor. This resulted in establishment of WG-30 (currently, WG-5: Homeland Security, Homeland Defense, and Civil Support).

In adapting to this changing environment, I also organized and led a special meeting with both DoD and DHS in November 2005, which focused on homeland defense and homeland security. This was the first joint meeting between the Department of Homeland Security (DHS) and the Department of Defense (DoD) analysts and served as a cornerstone for establishing the

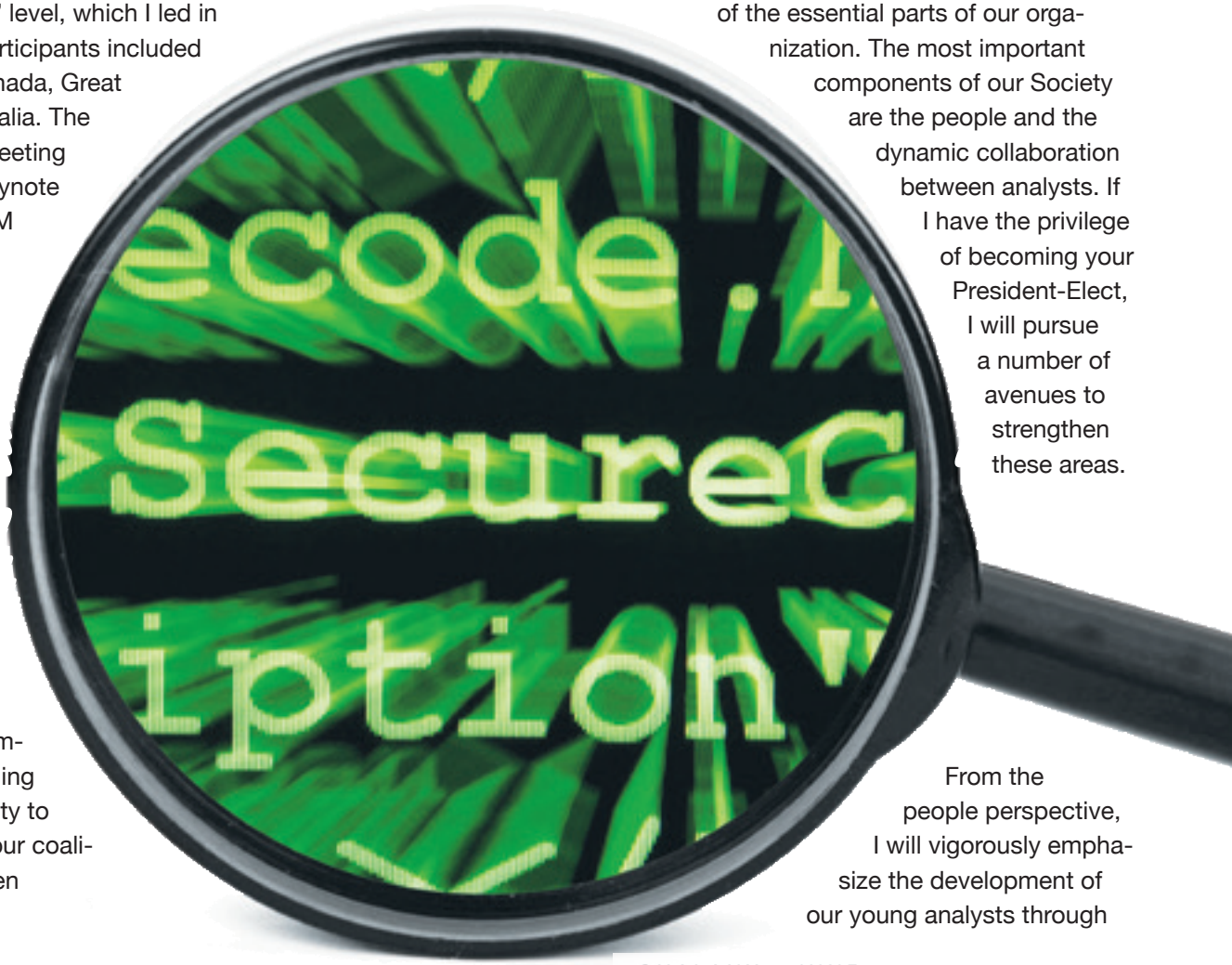
collaborative relationships the two departments now enjoy.

Getting outside my Air Force-centric comfort zone, I organized a maritime special meeting in Ottawa in October 2009 (Maritime Domain Awareness and Counter Piracy). Although there was already an existing body of maritime analytic work, this was a major step forward for USNORTHCOM. The meeting included our DHS and Canadian OR partners (DRDC CORA [Defence R&D Canada, Centre for Operational Research and Analysis]), and was the first MORS Special Meeting held outside the United States. This meeting institutionalized the analytic relationships between the maritime communities within the United States and Canada, and our new command, USNORTHCOM. Because this initial meeting was at an unclassified level, I pushed to have a follow-on meeting at the "Five Eyes" level, which I led in May 2011.The participants included analysts from Canada, Great Britain, and Australia. The highlight of the meeting (MDA II) was a keynote address from ADM Sandy Winnefeld, who charged us with a number of nontraditional issues, in which he needed solid quantitative assessments. This second meeting was the first classified "Five Eyes" meeting held by MORS and very important in expanding our Society's ability to collaborate with our coalition partners, when appropriate.

As a board member since 2009, I have served on the Management Committee (MC), led the Software Technology Committee, served as the program chair for the 81st MORSS, and worked with the executive council on the strategic refocus of the Society. My work on the MC has provided information and context on the financial issues facing our organization and given me insight into potential solutions. As the Software Technology lead, I implemented a new software package, being used today, improving efficiency at a much lower cost. These two experiences have helped me understand the financial challenges we have and given me additional ideas to more efficiently accomplish our mission.

From a meeting operations point of view, I have gained a great deal of experience from serving as the CG/WG Chair for the 79th MORSS, the Deputy Program Chair for the 80th MORSS, and the Program Chair for the 81st MORSS. However, my experience with rapid, short-notice, changes was put to the test for the 81st MORSS, when the venue changed from the US Military Academy at West Point to Alexandria, Virginia, only three months prior to the Symposium. The traditional18-month planning cycle had to be re-accomplished in just three months. We were all pleasantly surprised with more than 400 registrants, when we were expecting no more than 300. Compressing an 18-month process into three months and adding a virtual component was extremely challenging, and I want to publicly thank the entire team for helping to execute the 81st MORSS.

My work on the strategic refocus of the Society has sharpened my view of the essential parts of our organization. The most important components of our Society are the people and the dynamic collaboration between analysts. If I have the privilege of becoming your President-Elect, I will pursue a number of avenues to strengthen these areas.



From the people perspective, I will vigorously emphasize the development of our young analysts through

the Education and Professional Development (EPD) colloquia, the junior analyst tutorials at the symposia, and additional courses for the development of this new generation of analysts. For our more seasoned members, I will develop more continuing education courses at both live and virtual events. Essentially, I want to provide a more robust value to the people in our Society and an additional incentive for nonmembers to become part of it.

From the collaboration perspective, I will emphasize both live and virtual opportunities to enable greater interaction. We all have some experiences that have shown how collaboration has improved our analysis product and made an impact on a senior decision maker. As President-Elect, I will institutionalize more opportunities for this by fostering more Communities of Practice (CoPs), more local chapters, and more webinars.

Finally, to provide value to our people and enhance collaboration, I believe that virtual elements are essential to most of our events and activities, as we all continue to be challenged from a budget perspective. From the lessons I have learned by adding a virtual component to the 81st MORSS, I intend to expand these opportunities and make them more robust in future years.

From this perspective, as your President-Elect, I will work in four major areas to increase collaborative engagements for all members of our Society, both live and virtual.

The first area includes Special Meetings/Workshops, COPs, and the annual EPD colloquium. These types of interactions generally focus on OR disciplines and the cross-cultivation of ideas, whether from veteran practitioners or junior analysts. I will advocate and take advantage of all live, virtual, and hybrid opportunities.

The second area is the annual Symposium. This is the foundation event of MORS.As with the 81st and continuing into the 82nd MORSS, we are incorporating virtual opportunities. I will work with the incoming Symposium planning team to push for more virtual and hybrid participation opportunities for members unable to travel.

The third area is defined by education opportunities for our membership. Over that last several years, we have secured continuing education credit for those attending the CEU courses during the Symposium. For the 82nd MORSS, Kirk Michealson, FS, Dr. Niki Goerger, FS, and Trena Lilly are developing additional tutorial classes, which will provide more in-depth education in areas of OR practitioner practice. These courses and tutorials are not yet virtual, but I will be working with the operations team to allow future virtual access for remote attendees.

The fourth area is characterized by a number of innovative ideas including webinars, regional chapters, Lunch & Learn, and MOR talks. These ideas are at various levels of maturity. One example is the MORS Rocky Mountain Chapter, which has been meeting periodically for the past 18 months and recently has established a website and written a charter. As President-Elect, I will work closely with the members and leadership of the Society to fully develop these opportunities.

Summary

The experience I have gained as a presenter and leader in numerous WGs, CGs, special meetings, COCOM panels, and as a Board member has given me a solid understanding of what participants want and need from the Society. The single most important focus is developing and enabling analysts to provide actionable assessment products that inform their senior leadership.

As President-Elect, I am committed to working with each of you, our incoming President, Dr. Rafael Matos, and our sponsors to increase the value of our Society and directly support our senior leaders with their most critical issues. I would be honored to represent you and lead our Society through a very challenging time.

About the Author

Mr. Denesia is currently the Technical Director of the NORAD-USNORTHCOM Analysis Division. He also currently serves as the MORS Vice President for Meeting Operations.

Mr. Denesia has an undergraduate degree in mechanical engineering from Wichita State University (Magna Cum Laude) and a master's degree in operations research from the Air Force Institute of Technology (AFIT). He was commissioned in the US Air Force in 1974 and served nine years on active duty. During this time he was a flight test engineer at Edwards AFB, California; an AFIT student at Wright-Patterson AFB, Ohio; and an electronic warfare analyst with test and evaluation experience on numerous ranges at Nellis AFB, Nevada. He then spent an additional 21 years in the Air Force Reserve at the National Air and Space Intelligence Center (NASIC), Wright Patterson AFB, Ohio; and as the Deputy Director for Intelligence at Air Mobility Command, Scott AFB, Illinois.

Separating from active duty in 1983, Mr. Denesia worked as a defense contractor for Martin Marietta, Science Applications International Cor-

poration, and the MITRE Corporation. In 1988, Mr. Denesia re-entered government service as a civilian at Strategic Air Command, Offutt AFB, Nebraska; followed by civilian assignments to US Transportation Command, Scott AFB, Illinois; Office of Aerospace Studies, Kirkland AFB, New Mexico; and NORAD-US Space Command and NORAD-USNORTHCOM, Peterson AFB, Colorado.

Mr. Denesia has received numerous awards and decorations for both his military and civilian service to the Department of Defense. He is a graduate from Air War College, and in 2006, he graduated from the Defense Leadership and Management Program.

MORS Recommended Reading for Operations Research

Lynda K. Liptak, MORS Publications Chair,
Applied Research Associates, lliptak@ara.com

Do you like to discover innovative approaches to analysis that could be applied to your problem? Or do you like to read about operations research history and realize, "Hey, that is still a cool method to solve problems?" Whether you like old or new OR stories, or if you need a good reference for that technique that you can vaguely remember, we have the guide for you. Thanks to our well-read and diligent Michael Garrambone, MORS Past President, the MORS recommended reading list is now posted on the MORS website. It is an accomplishment that took much time and effort on several members' part and is well worth your perusal.

To find this list, go to the Research Publications & Reports tab and click the "all new MORS Reading and Resource List." It is a compilation of OR classics, recommended "must reads," and enjoyable OR foundation books. You will find there are historical, applied, theory, and reference materials for your reading pleasure.

Table 1 lists the categories and number of publications cited on this site.

Table 1. MORS recommended reading.

Category	Count
MORS limited editions	8
MORS books (heritage and methodological)	8
MORS Classic Books: Reprints and Contributions (online)	9
Operations research methods and techniques	21
Operations research history	18
Operations research biography	21
Doctrine and the strategic, tactical, and technical	24
Organizational, political, social, and governmental	23
Noteworthy texts from the past	19
References and resources	22

The publications committee is dedicated to maintaining this list for future researchers. Strengthen and expand your OR learning and professional development by selecting from these fine recommendations!

Leading MORS
Through Uncertain Times

Susan Reardon, MORS CEO, susan@mors.org

While the MORS membership and the national security analytic community focus on supporting the nation through a period of reduced resources while facing ongoing and increased threats, MORS is facing similar challenges. Unfortunately, we have seen the perfect storm form around us. The focus on meeting attendance within the federal government, sequestration, and budget constraints have demanded the MORS leadership undertake the same retooling, reshaping, and refocusing our nation is facing, and all with fewer resources.

Yet in times of adversity often come some of our greatest opportunities. Surviving has required MORS to function with a smaller staff and rely heavily on technology and the continued support and dedication of our talented volunteers and leadership.

We are fortunate that many of the new technologies and trends in business and organization management help to make organizations more mobile and agile. MORS had already begun to move to many of these new technologies, including voice over IP (VOIP) phones, cloud-based e-mail, and Web-based membership and registration systems. These systems, along with a newly implemented cloud-based file storage system, allow MORS staff to operate from any location, no longer requiring full-time rented office space. Our previous 3,240 square foot office suite has been replaced with part-time office "hoteling" space on an as-needed basis and off-site records storage. The MORS staff meets once a week in person and otherwise works from home.

Gone are the long commutes, snow days, and running home for the repairman. It is the challenge of being always on and connected, knowing when to turn off the MORS work and how to keep the dog quiet when on those conference calls (if you hear heavy breathing—honest; it is the dog)! The reassuring news is we are not alone. The trend of the flexible mobile work place is growing "The annual survey last year by the Society for Human Resource Management

found a greater increase in the number of companies planning to offer telecommuting in 2014. . . . Federal employees in Washington who worked from home during four official snow days saved the government an estimated $32 million" (Tugend 2014).

Working in this mobile environment may be more challenging for some of our experienced staff but is hardly noticed by the younger members of the staff. Liz Marriott, our millennial Director of Member Services, says, "Telecommuting is very common among my friends. About 50/50 work in an office or from home and they feel very comfortable with the virtual environment due to the many online courses they have taken in college." MORS' increased mobility has allowed us to reach further for staff and contractor support. For example, our website content manager, Miles Diamond, is contracted through an agency and located in Chicago. By the fall of this year, MORS will implement a new integrated website, online membership, registration, abstract submission, online publishing, and online membership collaboration platform that will replace five separate systems for a savings of more than $30,000 per year.

Liz Marriott, Director of Member Services (left) and Susan Reardon, CEO (right) are MORS full-time staff. Not pictured are MORS part-time staff and contractors: Miles Diamond, Web Content; Jennifer Ferat, Director of Industry and Institutional Partnerships; Shelbie Jenkins, Director of Meetings; Mike Noonan, Phalanx Graphic Design/Layout; Taniesha Sims, Director of Security; and Joan Taylor, Editor.

The focus of these new systems and technology is not just to reduce cost but also to give us better tools to create a new and refocused MORS. The demand by our community to exchange ideas and foster professional development continues to grow. MORS is actively and aggressively researching and implementing new programs and systems to support the community and maintain our position as the community's resource for professional development and growth. None of this would be possible without the indomitable team of MORS volunteers. While the staff are working to support and build new systems, our leadership and volunteers are doing the work of designing and developing new programs to serve our community and membership.

With the continued support of our volunteers, dedicated staff, and government sponsors, MORS will weather the storm. There is a clear and bright future combining the best of MORS traditions and the technology of tomorrow.

Reference

Tugend, A. 2014. "It's Unclearly Defined, but Telecommuting Is Fast on the Rise," *NY Times,* Mar. 7; www.nytimes.com/2014/03/08/your-money/when-working-in-your-pajamas-is-more-productive.html?_r=0.

Why MORS Matters

Dr. Wm. Forrest Crain, Director, Center for Army Analysis, william.f.crain.civ@mail.mil

SPONSOR'S CORNER

About the time that I received the MORS Army Sponsor baton from Mr. E. B. Vandiver, III, MORS was executing a special workshop. Hosted by USCENTCOM and cosponsored by the US Army and the US Air Force, representatives from across the globe gathered on November 5–9, 2012, at MacDill Air Force Base, Florida. Titled "Assessments of the Multinational Operations—From Analysis to Doctrine and Policy," their primary objective was developing useful information that could help inform doctrine, policy, and methods for the organizations and countries that execute operational assessments.

Were they successful? Thanks to the efforts of MORS members and associated friends, allies, and experts—well, I think they were. As of the writing of this article the information developed has gone beyond the boundaries of MORS articles and briefings. The US doctrine associated with how to do assessments has been revised and updated in drafts and final versions of Joint Publications (e.g., JP 3-0, JP 3-24, and JP 5-0). The deployed analyst course taught at the Center for Army Analysis (CAA) includes material developed from this session. The reports from the meeting have been distributed to international partners and allies. I hope to see even further development and usage of this material. This workshop provides a clear example on how MORS can bring together expertise, synthesize and develop usable information, then spread it out to the operations research community (and beyond!).

Why do I bring up this example? Quite simply, it demonstrates my belief in the power of an organization that is focused on national security issues and leverages the capabilities of quantitative techniques, models, simulations, and operations research. MORS provides a special environment where the Services, the Offices of the Secretary of Defense and the Secretary of Homeland Defense, the Joint Staff, international representatives, industry experts, academic professionals, and others can work together in a nonthreatening environment and develop insights to help leaders in the national security sector make better decisions.

In these times of decreasing resources and unprecedented global challenges, I see ever-growing demands for people who can understand complex

environments, apply critical thinking and quantitative techniques, effectively communicate their validated conclusions, and work interactively with the people to see how these insights can help solve problems and allocate resources. Operations research and its associated professions do this. When done right, the products are valued and the decision maker has information that makes her or his job much easier. The people that meet the demand for this analysis are found in the membership rolls of MORS.

MORS goes beyond the execution of meetings and symposiums. MORS provides a forum for the exchange of information across boundaries not normally crossed. The organization enables people like you and me to develop contacts, associations, and friendships with others in the profession that we would not meet otherwise. The publications provide a sharing of ideas, techniques, and processes. The education sessions provided by MORS develop our future analysts—"the seed corn" for the future of our organizations. MORS' recent expansion into virtual meetings and online postings provides a link to the latest happenings in operations research for the single ORSA in a staff that is far away from the traditional groups and teams of quantitative analysts.

To my fellow analysts in and out of MORS, I encourage you to keep growing in your skills and your critical thinking. I expect that the national security challenges in the future will grow in complexity and in scope. The most "wicked" of the "wicked problems" will require people with abilities to think creatively, critically, and quickly—yet leverage expertise in a networking manner so as to deliver timely and relevant insights to the decision makers of tomorrow.

And, I think these future analysts (for tomorrow, next year, and beyond) will be found in the rolls of MORS.

MAS Seeks Nominees for Three Top Awards

The Military Applications Society (MAS) is currently accepting nominations for our top three annual awards.

The Koopman Prize is a $500 award for the best published paper or report on military operations research topics directly related to the goals of MAS. The award honors the memory of Bernard Koopman (1900-1981), who was a pioneer in the field of operations research. He was active in the founding of the Operations Research Society of America (ORSA), later merged with TIMS to form INFORMS, and served as its president in 1956. Dr. Koopman served as an operations research liaison between the US Department of Defense and UK military establishments and NATO, and played a critical role in making operations research a permanent NATO activity.

The J. Steinhardt Prize is sponsored by the CNA Corporation. The prize is awarded for outstanding contributions to military operations research and is awarded for life work rather than for any particular contribution. The selection committee is composed of previous award winners. The award is accompanied by a plaque and a $2,000 honorarium.

In addition to these two awards, MAS is accepting nominations for the Seth Bonder Scholarship. The purpose of this scholarship for applied operations research in military applications is to promote the development and application of process modeling and operations research analysis to military issues. The scholarship provides funding to support the development of highly qualified individuals and promote the interchange of military OR research knowledge in conjunction with INFORMS.

The Bonder Scholarship consists of a grant of $4,000 that is intended to provide financial support for a promising young doctoral researcher. In addition, the award winner will be eligible for up to $1,000 of travel funding to support his or her participation in MAS presentation sessions and activities at the INFORMS annual meeting. INFORMS will waive registration fees for awardees. The tenure of the award is one year.

The deadline for nominations for the Koopman and Steinhardt Prizes is July 1, 2014. Nominations for the Bonder scholarship are due June 2, 2014. Details on submitting nominations can be found at www.informs.org/Community/MAS.

Ontologies Support M&S and Analysis in the Irregular Warfare Domain

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The Irregular Warfare (IW) Joint Operating Concept (JOC) lists counterterrorism, unconventional warfare, foreign internal defense, counterinsurgency, and stability operations as IW operations and activities, recognizing overlaps between them and applications outside the population-centric IW operational environment (OE) (US Joint Staff, 2010). The uniting feature of all of these operations is that the kinetic actions of traditional combat, while present, are insufficient for prosecuting or describing the operations. Human, social, cultural, and behavioral (HSCB) actions and understanding are required and often dominate.

Operations research analysts must carefully model and analyze the IW domain in order to provide accurate recommendations and assessments. Managing the complexity of the IW domain requires scoping the problem and assigning useful consistent descriptions. Semantic Web ontologies provide a means for formalizing descriptions of this domain.

Ontologies

Ontologies provide a structure for holding our knowledge about a domain and for using that knowledge. We have been increasing our use of ontologies to support modeling and simulation (M&S) and analysis within the Department of Defense (DoD) in the last half dozen years.

An ontology is one tool for describing a domain of knowledge. There is some fluidity in ascribing the title "ontology" to descriptions. Figure 1 (based on McGuinness, 2003) illustrates a spectrum of description formality, with the dotted vertical line dividing line nonontologies (on the left) and ontologies (on the right). Lee Lacy describes ontologies as formally described collections of terms and their relationships. A very important subset of ontologies consists of those that are machine readable. The Web Ontology Language (OWL) provides a method for encoding ontologies so they are machine readable (Lacy, 2005). The relationships form a structure and the terms form a controlled vocabulary for describing the domain.

The formal "is-a" requirement (from Figure 1) implies a structure: what

Figure 1. Descriptive techniques.

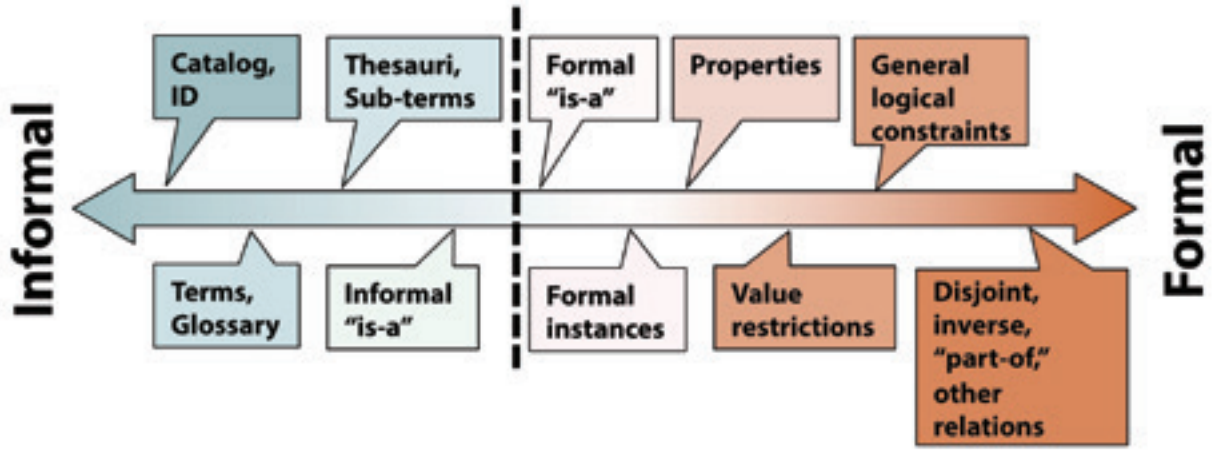
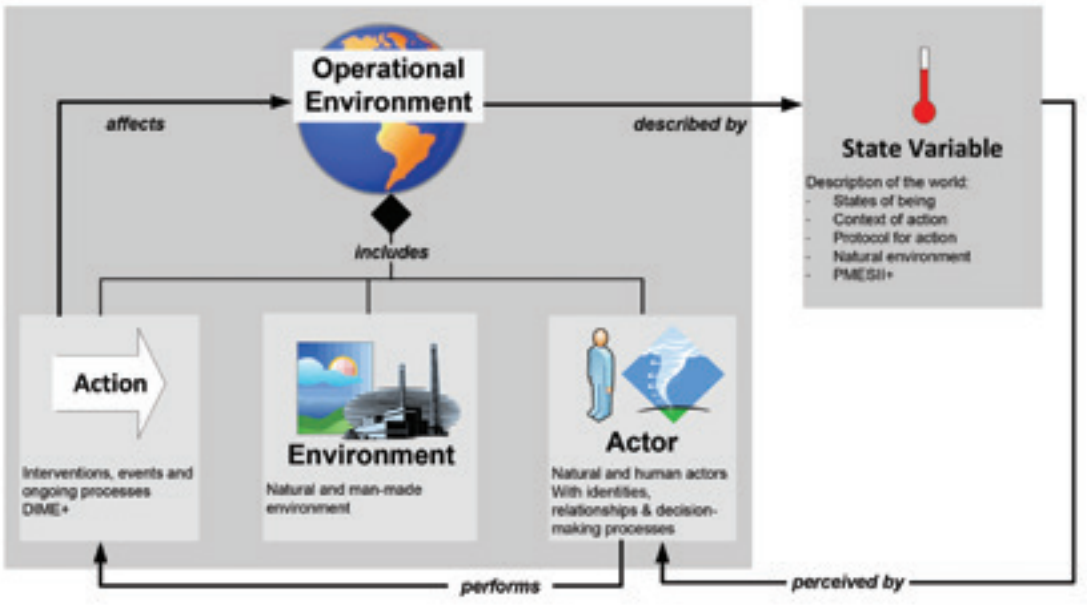


Figure 2. High-level concept diagram.



to more robustly represent the IW OE. TRAC also used the ontology to structure and examine links between various operational lines of effort (LOEs) metrics, and metrics elements (Hartley and Lacy, 2011). The ontology enabled TRAC to develop LOEs associated with each key actor/faction within the scenario being represented (Hartley and Lacy, 2011).

are the things that an element of the ontology might be one of? Naturally, the choice of the structure depends on the domain in question. It would be convenient if, in each case, there was a single, obvious, "correct" answer. Generally, there are several possibilities, with no clear rationale for making a choice. Fortunately, ontologies, unlike strict taxonomies, can have more than one structure and elements can have an "is-a" relationship with multiple structures and with multiple categories within a structure. It should be noted that "is-a" is not the only structure-forming relation. The "part-of" and other relations (lower right in Figure 1) also induce structures that may be included in an ontology. For example, a "pie" can be described as having a "crust" and a "filling" (parts of the pie), as well as having subtypes such as "apple pie," "cherry pie," and so on (is-a relations). The domain and the use of the ontology will determine the nature of the relations that are used.

Representing the IW Domain with Ontologies

In 2010, the US Army Training and Doctrine Command (TRADOC) Analysis Center (TRAC) asked for a metric ontology of IW. Authors Hartley and Lacy formed the team that developed the ontology. We divided the world as shown in Figure 2. The IW OE (that is, the "IW world") is made up of actions, environment, and actors. The actors are natural and human (individual and collective) entities, with identities, relationships, decision-making processes, and so on, who perceive and are influenced by the state of the world. They perform actions, which are interventions, events, and ongoing processes, that affect the operational environment (the actors, environment, and actions). The state of the operational environment at any given time is described by state variables (metrics) that give states of being, contexts of actions and protocols for actions. The state variables are classified using a PMESII+ (political, military, economic, social, information, infrastructure, kinetics, environmental) structure.

This work focused on creating an ontology of the state variables or metrics, shown in the right-hand part of the figure. TRAC used that ontology to enhance the existing model (previously developed through compilation of several extant IW metric taxonomies) Subsequently, Hartley expanded the ontology into a total ontology (including the actions, environment, and actors of the figure) of IW and used it to improve his DIME/PMESII VV&A Tool (Hartley, 2009, 2011a, 2011b). The ontology defines the IW elements and their connections and provides the basis for a "connectivity check" within a model's subelements. It does not, nor is it intended to, describe the specific interactions among the various model elements of IW; however, it does allow for checking as to whether all the components that are desired are, in fact, represented. It should be used as the basis for coordinating the use and creation of multiple models of IW. It can also be used to identify gaps in social theories (Hartley, 2012).

In 2012, TRAC contracted for work to extend the metric ontology into a complete IW ontology. Hartley also led the team in this effort. Recognizing that use of the LOE doctrinal terminology is typically only used by US Department of Defense (DoD) and coalition military forces and agencies, Hartley's work focused on bringing to TRAC an expanded ontology and creating ontological generalizations

of the LOEs, called goal-task-owner (GTO) sets, for use by significant non-DoD parties to IW (Hartley and Lacy, 2013). Figure 3 illustrates the large number of actors (owners), each with its own agenda (sets of goals and tasks) that may be present in a large IW operation. Any model or analysis of the situation needs to take all of these into account.

Figure 3. Potential range of actors and agendas in an IW operation.

This latest part of the ontology has just been completed and distributed. We foresee numerous uses in the future.

Using Ontologies with M&S in IW Analysis

In 2007, the Office of the Secretary of Defense (OSD) used the Oz wargame integration toolkit to record the first IW analytical baseline in the Department of Defense, the Africa Study. In the Africa Study, moves of a wargame were entered into multiple social simulation models that determined the effects of the moves. With Oz, the research team described the actions, actors, and whole of government moves in an OWL ontology at the strategic level of war. The categorization of moves into the general and specific categories of the machine-readable ontology facilitated machine analysis of trends in the game (Duong and Pearman, 2013).

In 2010, US Army TRAC sponsored SIMmiddleware as a key element within TRAC's ongoing development of the IW tactical wargame (TWG). SIMmiddleware, a continuation of Oz by the same inventor, Deborah Duong, took the application of ontologies to simulation analysis a step further by giving ontologies an active role in the integration of simulations. An inference engine acting on the ontologies computed move translations between social models and recognized simulation states, such as indicator states and measures of effectiveness, important to the study question. In the TWG analysis, SIMmiddleware expressed the conceptual model of the study as the "hub" of ontologies arranged into a hub and spoke design (Figure 4). The spokes were the ontologies that represent the native objects and relations of the different social models of the study, including the Nexus Cognitive Agent Simulation to model key leader networks, and the cultural geography simulation to model popular support and infrastructure. Translation ontologies translated back and forth between the concepts of the conceptual model of the study and the concepts of the simulation models. These translation ontologies were probabilistic ontologies that used Bayesian inference to translate moves that did not have an exact definition, or when resolutions were crossed from a more general to a more specific move.

Figure 4. Hub and spoke ontology design.

The "hub and spoke" design facilitates modular integration of disparate models with diverse languages into a single consistent language of the study, which clearly demarcates what is being studied and what is not. There is a rule of thumb to know what goes into a conceptual model of a study: If a difference between models matters to the results of the study, then that difference should appear in the conceptual model, otherwise it is just an implementation difference that serves the same function, and therefore is not part of the modeled con-

cept. By defining the terms of what is under study, ontologies flag inconsistencies, or the use of a concept not under study, helping to bound the study for analysis (Duong and Bladon 2012, Duong 2012).

In the TWG analysis, ontologies were also used to define simulation states, such as indicators and measures of effectiveness, important to the strategies of the wargamers. By keeping a record of the decision points, branches and sequels, and goals of the wargamer's strategy, the ontology noted information that was used to automate the wargame in multiple constructive runs for Monte Carlo analysis. The hierarchical arrangement of the ontology, from general to specific, provided a variety of views on what happened in the wargame, facilitating the analysis of trends. For example, within the IW TWG analysis, the mutual information score was measured between indicators and wargamer actions at several levels of generality in the ontology to find out what actually triggered wargamer decisions at the right level of generality. The many levels of generality of the ontology helped to define simulation states that mattered to the study question, eventually to be put into a Markov process that summarized the trends of multiple simulation runs (Duong and Bladon 2012, Duong 2012).

In 2013, US Army TRAC sponsored a study of modeling civil military operations, which included research on how ontologies may support verification, validation, and accreditation (VV&A) of social simulations and their federation in a study. SIMmiddleware was enhanced with a Shum ontology that defines conceptual support for a theory. This ontology kept track of every time trends in a social simulation supported the social theory that they were supposed to represent. If the output of the social simulation matched the trends that would be expected in the social theory, the model would be considered more valid. However, to be valid, a social simulation must also match real-world processes through the social theory it represents. Ontologies assisted here too: the Markov processes that summarized the trends of multiple runs of the simulation could be measured against real-world data put in another Markov process, using a probabilistic distance, to find an objective "validation" score. Ontologies helped in the comparison by offering multiple levels of generality to describe the simulation state for comparison across multiple dimensions (Duong and Pearman, 2013).

Ontology Application

Starting in 2007, TRAC collaboratively undertook an extensive research effort to examine the current state of capabilities to examine and analyze doctrine, organization, training, materiel, leadership (DOTML) change and conduct of operations decisions associated with the IW OE. TRAC performed an extensive literature review, including but not limited to Galula (1964), Cordesman (2005, 2007), Stephen Downes-Martin (2010), Paul K. Davis (2009), Glenn and Gayton (2008), Kilcullen (2010), and Hartley (numerous items). TRAC also extensively leveraged prior work such as

- OSD Cost Assessment and Program Evaluation (OSD CAPE),
- Defence Science and Technology Laboratory (Dstl) UK Ministry of Defence (UK MoD),
- US Marine Corps Combat Development Command Operations Analysis Division (MCCDC OAD),
- Joint Staff J8,
- the TRADOC G2 Intelligence Support Activity (TRISA), and
- ongoing analysis in current operations in Iraq (Operation Iraqi Freedom, OIF) and Afghanistan (Operation Enduring Freedom, OEF).

From that early research emerged the metric-state-vector concept for capturing the current state of the IW OE to facilitate analysis. An examination of the existing constructs that identified and grouped such metrics led to a decision to group metrics in a PMESII taxonomy that could also be rearranged, as necessary, into metrics informing progress toward LOE desired end states. The initial consolidation of metrics clearly indicated that a taxonomy would not be sufficient to adequately represent the metrics and their relationships within any grouping—an ontology was required. Ontologies lend themselves well to the essential elements of analysis (EEA) and measures of performance/effectiveness (MOP/MOE) structure central to Army and DoD analyses. They additionally enable the concept of decomposition; the method of breaking down elements of the OE to levels where the interactions and effects can be reasonably understood, then re-aggregating those elements to the level(s) required to effectively inform decisions. Both the decomposition and the re-aggregation are greatly enabled by understanding the key relationships between the environmental elements and the metrics, leading to a much more robust and nuanced understanding of the OE. An important concept was using the metric-state-vector concept to attempt to understand movement between the states, identify possible tipping points (Gladwell, 2009), and attempt to reduce the range of "black swan" possibilities or their impacts (Taleb, 2007; Perla, 2008).

Conclusions

Attempting to solve problems without an understanding of the key elements involved, their relationships,

and potential second- and third-order impacts is typically challenging. Within an environment as complex as IW, attempting such is fraught with risk. Without robust representations of the range of elements and interactions within an IW OE, decision analysis efforts may not adequately support senior leader decisions concerning equipping forces, organizing forces, and conducting operations within the IW OE. Semantic Web ontologies provide a means for formalizing descriptions of the IW domain and of particular models of the IW domain. It is recognized that the capture of the "complete" range of elements and interactions is not possible. However, this effort has sought to capture the most relevant elements and relationships, identify associated metrics, and anticipate metric variation in order to provide a structural construct wherein effective analysis associated with the IW OE can be attempted. Operations within IW OEs are not going away anytime soon. The analytic community must continue to expand its capabilities to support related decisions.

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About the Authors

Dr. Dean Hartley was educated as a mathematician, but has worked for 45 years in the field of operations research. Currently, most of Hartley's consulting involves irregular warfare and verification & validation. He has written a book, several book chapters, many articles and technical reports, and has presented his works in innumerable venues. Hartley is a former Vice President of the Institute for Operations Research and Management Science (INFORMS), a former Director of the Military Operations Research Society (MORS), and former President of the Military Applications Society (MAS). He reads science fiction and enjoys shooting large holes in paper targets.

Dr. Lee Lacy is a leader in the use of Semantic Web ontologies for military applications and has more than 20 years of experience in modeling and simulation. He authored *OWL: Representing Information with the Web Ontology Language* (Trafford, 2005) and has written many proceedings articles for simulation conferences. He is a Certified Modeling and Simulation Professional (CMSP). Dr. Lacy has managed and performed on many contracts including research efforts for DARPA, AFRL, Army RDECOM, and TRAC. His research has focused on simulation data interchange and Semantic Web ontologies.

Dr. Deborah Duong is computational social scientist with more than 25 years of experience in social simulation. Dr. Duong invented eight tools used in military analysis, including the Nexus Cognitive Agent Simulation, the Oz Wargame integration toolkit, and the SIMmiddleware simulation analysis toolkit. Dr. Duong's models played central roles in major DoD analyses, including DoD's first analytical baseline (the Africa study), and two iterations of the US Army's tactical wargame, simulating sociocultural topics such as corruption, popular support, key leader engagements, and terrorist networks. She is the current chair of the MORS Working Group on Social Science. She has three lovely adult children, Sonny, Lana and Anna.

Mr. Paul Works is the Director, Methods and Research Office, TRADOC Analysis Center (TRAC), Ft. Leavenworth, Kansas. He has 27 years of experience as a physicist and operations analyst working for the US Navy and US Army. Ongoing efforts include cyberspace operations representations; Army analytic community standards coordination; analysis impacts on, and relevance toward, senior leader decisions; and leadership development tools for classrooms and units in garrison. Paul spends his spare time working wargame modules for the Advanced Squad Leader game system and in activities with his family. Paul and his wife Patti have two great children, James and Leota.

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USING SIMULATED ANNEALING TO SOLVE A PROBLEM OF "ECOLOGICAL" INFERENCE"

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This article presents the use of simulated annealing to deduce 88 sets of three quantities—the number of escorts, the number of attacking U-boats, and the number of merchant vessel sinkings—from a few lines' worth of summary tables. This is a problem of "ecological inference," that is, the drawing of conclusions about individuals or subgroups from data about a whole population.

The seminal books *Methods of Operations Research* (Morse and Kimball, 1946) and *Anti-Submarine Warfare in World War II* (Sternhell and Thorndike, 1946) present summary tabulations of 88 battles between German submarines (hereinafter, U-boats) and convoys that took place in the North Atlantic during 1941 and 1942. The wartime analysts chose this period with homogeneity expressly in view, citing in particular that it starts at the Germans' introduction of wolf-pack U-boat tactics and ends at the Allies' introduction of the escort carrier. Of course, the US entry into the war near the middle of this period changed the war in many ways, but the wartime operations researchers were probably correct in assuming that it made little difference in the outcome of a convoy battle of given size.

The principal point of the wartime analyses was to refute the "too many eggs in one basket" objection to large convoys. It was readily shown that the number of merchant vessels lost to an attack did not depend upon the size of the convoy, so that large convoys are actually safer (Sternhell and Thorndike, 1946, p. 106). Secondarily, the analysts sought to establish the vessels-lost numbers' dependence upon the remaining variables: the number of U-boats attacking and the number of warships escorting the convoy.

The principal variables are *m,* the number of merchant vessels in the convoy; *n,* the number of attacking U-boats; *c,* the number of convoy escorts; and *k,* the number of merchant vessels sunk as a result of the attack. (Tantalizingly, the caption in Morse and Kimball also includes *l,* the number of U-boats sunk in the engagement—but no values of *l* appear in the table!) Tables 1, 2, 3, and 4 show the data as presented in the above-cited sources, binned according to one variable and with the values of the others shown as averages over the bins. For example, the second row of Table 1 says that there were eight pack attacks on convoys with between 15 and 24 merchant vessels: in these convoys, the mean number of merchant vessels was 20.4, the mean number of escorts was 6.5, the mean number of U-boats was also 6.5, and in these engagements a mean of 4.8 merchant vessels were sunk, or 0.7 sinkings per U-boat.

From these data the wartime operations researchers inferred that the num-

Table 1. North Atlantic U-boat pack attacks on convoys, 1941–1942, binned by m, the number of merchant vessels; k is the number of merchant vessels sunk, c is the number of escorts, and n is the number of U-boats.

Size of convoy, in merchant vessels *m*	Number of pack attacks	Mean *m*	Mean *c* (escorts)	Mean *n* (U-boats)	Mean *k* (Sinkings)	*k/n*
0-14	1	11.0	4.0	4	7	1.8
15-24	8	20.4	6.5	6.5	4.8	0.7
25-34	11	29.7	6.8	5.1	5.6	1.1
35-44	13	38.5	6.1	5.8	6.1	1.1
45-54	7	48.3	6.5	5.2	4.9	0.9
55 and over	2	62.5	8.0	7.5	9	1.2
	Total: 42					

Note: From Sternhell and Thorndike (1946), Table 3, p. 106. Morse and Kimball (1946) give a similar table, less the top and bottom rows, p. 46, Table 4.

Table 2. North Atlantic convoy engagements, 1941–1942, binned by n, the number of U-boats; c is the number of escorts, and k is the number of merchant vessels sunk.

n (U-boats)	Mean *n*	Engagements	Mean *k* (sinkings)	Mean *c* (escorts)
1	1	29	0.9	6
2-5	3.4	32	3	7
6-9	7	22	4	7
10-15	14	5	6	8
		Total: 88		

Note: From Morse and Kimball (1946), p. 47, Table 5.

Table 3. North Atlantic convoy engagements, 1941–1942, binned by c, the number of escorts; n is the number of U-boats, and k is the number of merchant vessels sunk.

c (escorts)	Mean *c*	Engagements	Mean *k* (sinkings)	Mean *n* (U-boats)
1–3	2	6	4.5	3
4–6	5	42	3.4	4
7–9	8	25	3	4
10–12	11	13	1.1	2
13–15	14	2	2	10
		Total: 88		

Note: From Morse and Kimball (1946), p. 47, Table 6.

Table 4. Alternative binning of 1941–1942 North Atlantic convoy engagements by c, engagements, and mean k/n.

c (escorts)	Mean *c*	Engagements	Mean *k/n*
1–4	3.4	22	0.88
5–9	6.7	51	0.75
10–15	11.1	15	0.34
		Total: 88	

Note: Sternhell and Thorndike (1946), p. 108.

ber of sinkings *k* tended to be about 5 times the ratio of U-boats to escorts, *n/c*. They observed, however, "unfortunately a sorting according to *c* (i.e., Table 3) has also meant a partial ordering according to *n*" (Morse and Kimball, 1946, p. 47) This fact, probably ascribable to the increase in both variables as the war went on, threatened the utility of the tabulated data in arriving at any generalization that involves the product or ratio of these variables.

Also, and perhaps more debilitating, the simple relationships sought by the wartime analysts made no account of the operation of chance.

Any remedy of these shortcomings had best begin with the full set of 88 engagements, not the summary tables. However, the wartime analysts do not seem to have left us with this list, as such, and to attempt to create it from other sources (e.g., Blair 1996) turns out to entail difficult definitional questions regarding, for example, when one engagement (of a given convoy) ended and the next began. To create such a listing and then to use it in support of some theory of convoy warfare would invite the skeptical reader to suspect that the knowledge of the theory might have influenced the formulation of the data set.

Therefore it is desirable to recreate the 88 engagements purely from the tables themselves.

A Look at the Data

Before trying to explicate the tables, we must examine them in detail.

First, Table 1 deals in "pack attacks," of which it contains 42, whereas

Tables 2-4 deal in "engagements," of which they contain 88. Inasmuch as the times and places are the same, we may suppose that "pack attacks" are a subset of "engagements"; later, we will revisit the question of what subset they might be. Table 1 also reveals that there was just one engagement with fewer than 14 merchant vessels, and that it had four escorts, four U-boats, and seven sinkings.

Second, no bin has a lower limit of zero. Although it is clear that any attack must involve at least one U-boat, and one might take it for granted that any convoy would have at least one escort, it is probably untrue that any U-boat encountered would sink at least one merchant vessel. We may therefore conclude that the cases have been restricted to those in which at least one merchant vessel was lost. Inasmuch as the original analysis was done before the war ended, such a restriction makes sense because there would have been no way to be sure that all instances of fruitless attacks were known.

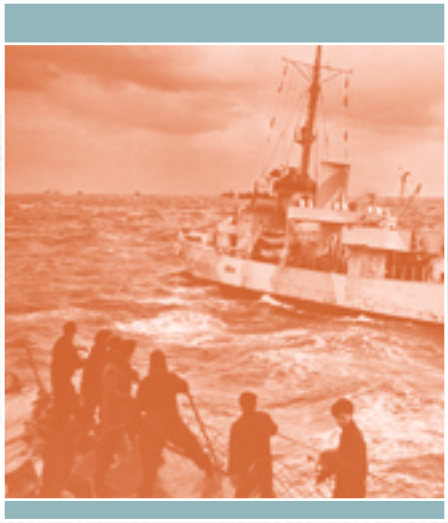
Estimates of the total number of escorts, U-boats, and sinkings over the 88 engagements are easy to make by simply multiplying the means by the numbers of engagements. From Table 2, for example, we can multiply 1 by 29, 3.6 by 32, and so on, and then sum to find the approximate number of U-boats involved in the 88 engagements. This process suggests that in the 88 engagements we should expect totals of approximately 590 escorts, 355 U-boats and 250 sinkings. (Of course, some of the escorts and U-boats may well have been the same physical vessels, appearing in more than one engagement.) Similar, but different, results arise from doing the same thing in Table 3—underscoring the desire for a complete decomposition into 88 engagements.

The sources applied somewhat inconsistent rounding to the data in Tables 2 and 3: some entries are integers and some have a single decimal of precision. But all are ratios of counts, and should really be fractions, so the idea of using decimal notation to express the precision of measurements is not applicable in this case. Because we will be trying to match these numbers, we should recover their correct values: doing so is possible in most cases. Assuming that the wartime analysts rounded correctly, Table 2's mean of 0.9 sinkings in 29 engagements ought really to be 26/29 and an average of 3.6 U-boats in 32 engagements is 115/31. In Table 3, 4.5 sinkings in six engagements points to a total of 27, with no damage done in rounding, and the average of 3.4 sinkings in 42 engagements indicates a true total of 143.

Yet the discrepancy in totals, which remains quite large, indicates that considerable rounding is present in the averages that are presented as integers. Table 3's figure of 1.1 for the mean number of sinkings in the 13 engagements with 10–12 escorts is hard to pin down: 14/13 is 1.08, 15/13 is 1.15, and each could be rounded to 1.1. Similarly, the average of 3.4 in a set of 32 could be 109/32 (3.406), but it could also be 108/32 (3.375) or 110/32 (3.4375). We will deal with these ambiguities by making their resolution part of the solution process itself.

Table 4 is a great boon, not only in that it gives us information on *k/n,* but also in that it bins *c* in a fashion different from that of Tables 1 and 2. In the original version of Table 4, the number of engagements in the bottom row is printed as 75; only after puzzling over that entry many times did I conclude that it must be a miscopying of 15, which is plausible in light of the resemblance of a "7" and a "1," and which makes the total come to the correct 88.

Going back to Table 1, each row's figure for *k/n* is equal to the row's *k* divided by the row's *n*. Although this is certainly a valid quantity to calculate, it is not necessarily the same thing as the pack attacks' average *k/n.* For example, suppose, however improbably, that the bottom row's two attacks



involved one attack by 14 U-boats and another by one U-boat, and that nine merchant vessels were sunk in each case. Then the average *n* is 7.5 and the average *k* is 9, as indicated, but in one case *k*/*n* was 0.64 and in the other it was 9, which could very reasonably be interpreted as an average *k*/*n* of 4.82, not 1.2.

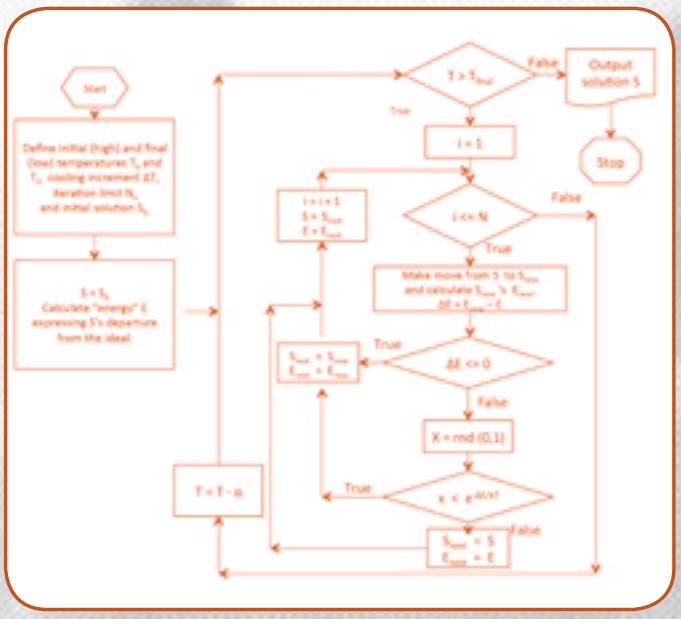
Simulated Annealing

We will recover the original engagements from the summary tables, using simulated annealing.

Simulated annealing is a numerical method of approximately optimizing a complicated function of many variables. The obvious means of solving such problems—given today's plentiful and cheap computational power—is to start somewhere and then make small steps to adjust the solution, rejecting steps that do not result in improvements. The trouble with that method is that it can get stuck in a local optimum: the peak of a hill that is not the tallest mountain or, in the case of minimization problems like the one at hand (we will be minimizing squared error), the bottom of a valley that is not the deepest crater. The idea of simulated annealing is that it, like physical annealing, will tolerate a certain amount of change in the wrong direction, the better to end up at an overall optimum.

There are multiple variants of simulated annealing. Here, we will use that presented by Salamon et al. (2002), of which the basic approach is shown in Figure 1. The set-up is specified in terms of a high "temperature" at which the process will start, a low temperature at which it will end, an increment by which it will cool, and, an iteration limit, whose use will become apparent, that does not have an obvious thermodynamic analog. Then an initial solution is created, usually at random or nearly so, and its departure from the ideal is expressed as an "energy."

Figure 1. Basic scheme of simulated annealing.



The annealing process then begins, and continues as long as the temperature exceeds the lower limit. In this process, a "move" is made that creates a new solution, whose energy is calculated. If the change in energy is negative, then the new solution is closer to the ideal and it is adopted. If the change in energy is positive, the new solution may be adopted anyway, based on a random choice (driven by *x,* a random variable uniformly distributed on (0,1)) and conditioned on how positive (i.e., bad) the change is; this step is the means by which simulated annealing avoids getting trapped in local optima.

This process continues through the chosen number of iterations, at which time the temperature is reduced. Note that the reduction in temperature not only brings the process closer to an end, but also reduces the level of tolerance for changes in the wrong direction.

In the expression $e^{-\Delta E/kT}$, *k* is Boltzmann's constant, which makes the exponent dimensionless. In this nonphysical application, there is no

Table 5. Scoring of a candidate solution's sinkings, binned by U-boats.

Scoring criteria	Mean sinkings *k*, binned by U-boats *n*				Sum of scaled squared differences
Upper limit of U-boats *n*	1	5	9	15	
Lower limit of U-boats *n*	1	2	6	10	
Mean sinkings *k*	0.9	3.0	4.0	6.0	
Candidate solution's mean sinkings *k*	3.6	3.1	2.8	3.0	
Squared difference	7.506	0.005	1.417	9.0	
Scaled squared difference	8.373	0.002	0.354	1.5	10.229

Table 6. The 88 engagements, as recovered by simulated annealing.

Escorts	U-boats	Sinkings	Escorts	U-boats	Sinkings
14	12	2	6	7	5
14	8	2	6	7	5
12	6	1	6	7	2
12	6	1	6	6	3
12	2	1	6	6	3
12	2	1	6	6	2
12	1	1	6	2	1
11	1	1	6	1	1
10	2	1	6	1	1
10	2	1	6	1	1
10	2	1	6	1	1
10	2	1	5	15	7
10	2	1	5	8	10
10	2	1	5	5	8
10	1	1	5	5	7
9	15	6	5	5	6
9	9	10	5	5	6
9	9	4	5	4	4
9	6	7	5	2	1
9	6	4	5	1	1
9	6	1	5	1	1
9	3	1	5	1	1
9	2	1	5	1	1
9	1	1	4	6	1
8	5	4	4	6	1
8	4	4	4	6	1
8	4	2	4	6	1
8	3	1	4	4	7
8	1	1	4	3	1
8	1	1	4	2	1
8	1	1	4	1	1
7	5	4	4	1	1
7	5	4	4	1	1
7	5	4	4	1	1
7	5	4	4	1	1
7	5	3	4	1	1
7	1	1	4	1	1
7	1	1	4	1	1
7	1	1	3	2	1
7	1	1	2	6	7
6	15	7	2	4	11
6	12	8	2	1	1
6	8	12	2	1	1
6	7	7	1	4	6

basin, the wider the rim. (Salamon et al. [2002] relate this idea to the law of Arrhenius [or Cramer], according to which deeper basins tend to have longer rims.)

reason not to set *k* equal to unity.

We may analogize the simulated-annealing procedure to an effort to find the deepest part of a lake, given a rowboat, a sounding line, and a buoy. One goes out, makes a sounding, places the buoy at it, moves the boat a little, and makes another sounding. If the later sounding is deeper, we move the buoy to that site; if not, we leave the buoy where it is, again move a little, and make another sounding. Whenever we find the water to be "too much shallower" than it is at the buoy, we go back to it and start over; and as the day progresses we shrink our definition of "too much shallower." The thoughts behind this method are a) that we want to guard against finding only a local pit, and b) that the deeper the

Recovering the Engagements by Simulated Annealing

In the task at hand, the solutions *S* will be lists of 88 engagements' numbers of U-boats, escorts, and merchant vessel sinkings. They will also include choices for the three options regarding rounding. The energy *E* will be the solutions' departure from the unknown original data, as judged by the comparison of the solutions' binned averages from those of the wartime data as given in Tables 2–4.

Initialization

The high and low limits of temperature are set at 2,000 and 0.1 respectively, the increment of cooling Å is 0.995, and the iteration limit at 200. It must be admitted that these values were found by trial and error in this particular case. They have the property of bringing the system to a low-energy solution in a reasonable amount of computer time.

Then an initial strawman solution, a set of 88 values of *c, n,* and *k* as defined above, is concocted by setting each of the entries to unity, and then randomly incrementing them (except that none is allowed to exceed 15, the largest entry given in the tables) until the totals are equal to 590 escorts, 355 U-boats, and 250 sinkings as estimated above. Toggles representing the rounding choices are set at this time as well.

Energy as Squared Error

Energy is calculated by finding the solution's departures from the summaries in Tables 2–4, squaring the differences,

normalizing by dividing by the table value, and summing. Table 5 shows the part of this calculation that relates to the means of the cargo vessel sinkings, binned by the number of attacking U-boats. The top three rows are from Table 2; the next row shows binned sinkings from a candidate solution, starting with 3.6 sinkings as the average number of those cases in which the number of U-boats was one. The row after that shows the sum of the squared differences between the actual means and those of the candidate solution, and the bottom row shows these squares scaled to the true values (e.g., 7.506/0.9 = 8.373), so that innately larger quantities do not exert extra influence. The sum of these squares (bottom right) is the contribution to the energy of the candidate solution caused by its departures from reality in terms of mean sinkings as binned by the numbers of attacking U-boats.

Tables 3 and 4 of original data are treated similarly, and the solution's total score is the sum of the contributions from all the tables.

The Main Step

In the main step, the existing solution is perturbed and the energy is recalculated.

This perturbation consists simply of picking one of the values, *c, n,* or *k,* in one of the solutions and incrementing it or decrementing it by unity. If doing so would result in a value less than 1 or greater than 15, the movement is made in the opposite direction instead.

As shown in the flowchart and explained earlier, the new solution is retained if it is better, and if it is not better, it might be retained anyway.

Table 7. Differences between solution and Morse and Kimball (1946) data, binned by U-boats.

n (U-boats)	Difference in mean *n*	Difference in engagements	Difference in mean *k* (sinkings)	Difference in mean *c* (escorts)
1	0	0	-0.1	0
2–5	0.0	0	0	0
6–9	0	0	0	0
10–15	0	0	0	0

Table 8. Differences between solution and Morse and Kimball (1946) data, binned by escorts.

c (escorts)	Difference in mean *c*	Difference in engagements	Difference in mean *k* (sinkings)
1–3	0	0	0
4–6	0	0	0.2
7–9	0	0	0
10–12	0	0	2/13
13–15	0	0	0

Table 9. Differences between solution and Sternhell and Thorndike (1946) data, binned by escorts.

c (escorts)	Difference in engagements	Difference in mean *c*	Difference in mean *k/c*
1–4	–1	0.0	0.05
5–9	1	0.0	0.08
10–15	0	0.1	0.18

Halting

Upon reaching the preset lower limit of temperature, the algorithm halts and presents the best solution that it has found so far.

Refinements

I found that if an improvement in terms of lowered energy has just been made, a repetition of the same move (i.e., again incrementing or decrementing the same *c, n,* or *k* within the same engagement) was sufficiently likely to bring about another improvement that it was worth trying—if it did not push the value below 1 or higher than 15. This refinement reduced the amount of computer time used. Any risk that it would somehow channel the solution in a bad direction seemed to be counteracted by simulated annealing's willingness to tolerate occasional wrong-direction excursions.

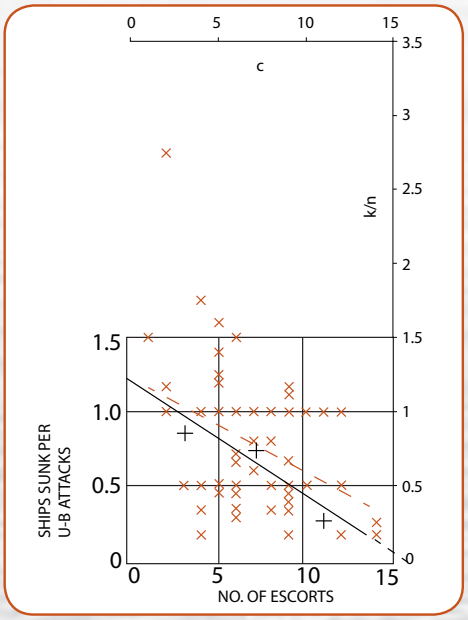
Results

After many days of computer time, a solution, shown in Table 6, was found. Although this solution has been reached in a complicated and perhaps seemingly haphazard manner, it can be checked with grade-school arithmetic by creating from it a set of tables that are binned in the same manner as the originals: Tables 7 and 8 show the differences between the solution and the Morse and Kimball (1946) Tables 2 and 3; Table 4 shows the differences between the solution and the Sternhell and Thorndike (1946) Table 4. In addition, the solution has the required one engagement with four escorts, four U-boats, and seven sinkings.

The levels of precision are those in the original data, with the exception that the quantity 2/13ths is expressed as a fraction to show how the program resolved the decimal ambiguity discussed above.

I doubt that there are any alternative solutions from that of Table 6, and if there are, they are not much different. A number of runs ended early for one reason or another, and they had a great many battles (i.e., rows) in common with Table 6.

Figure 2. The 88 engagements as recovered by simulated annealing.



When trying to map these 88 engagements to those in the narrative presented by Blair (1996), currently the last word in detailed history and historicism of the Battle of the Atlantic, or on the narrative presented in the history commissioned by the Ministry of Defence (1989), one soon comes to realize that the wartime researchers' account may differ with Blair's even though each may be correct in its own terms: discrepancies can arise from varying definitional, if not near-metaphysical, distinctions such as what to do about merchant ships that became "stragglers" as a result of a convoy battle and are sunk later, and what divides a single engagement from two successive engagements involving the same combatants, or subsets (or supersets) thereof.

The above points to a problem not always recognized by those who propose quantificative work in the study of combat: even in the U-boat war, which has been called the best-documented conflict in history (van der Vat, 1988, p 385), the cross-source comparison of summary data can be difficult or impossible.

The heavy black portion of Figure 2, including plus-sign markers and the solid trendline, is the original graph from Sternhell and Thorndike (1946, p. 108) from which they extrapolated that 16 escorts would confer complete immunity. The plus signs indicate Sternhell and Thorndike's data on means as shown in Table 4 above, and the heavy line is their least-squares fit thereto—unweighted by the numbers of engagements. The red Xs, with their dashed trendline, are the 88 recovered engagements. (Far fewer than 88 Xs can be seen because some are superimposed.) The benefit of escorts is still clear, albeit not quite so strong, but the constellation of recovered engagements suggests a much stronger role for chance than did the original graph. Nor is there any reason to think that a least-squares linear regression will provide the best trend line, and in fact the extrapolation to zero losses for a finite number of escorts, argues against linearity. An exponential fit would avoid the fantasy of zero losses, but it lacks any other justification in terms of the combat processes involved.

Author Statement

This paper is not a product of the Center for Naval Analyses.

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About the Author

Brian McCue is a graduate of Hamilton College and the Massachusetts Institute of Technology. He has worked as a defense analyst for 31 years, first in private industry; then in the Department of Defense, where he wrote *U-Boats in the Bay of Biscay* as a Senior Fellow at the National Defense University; then at the United States Congress's Office of Technology Assessment; and now—since 1996—at the Center for Naval Analyses.

Though his work has taken many forms, Dr. McCue says that what he likes best is "to match real-world data to quantitative formulations that make sense in terms of physical reality.

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Factoring Climate Change and Extreme Weather Events into National Security Analyses

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When people think of US national security issues, they often think about them from a military perspective, such as defending against hostile forces. It is well known that weather conditions can impact local or regional military operations and be a decisive factor in the outcome. Therefore, weather conditions are taken into account during operational planning and are tracked throughout a mission to enable modifications for optimum results.

Less well known are the impacts of global climate change and related extreme weather events on national security. The US DoD has considered such impacts from both internal and external perspectives. From the internal perspective, it has been surmised that the preparedness of US military forces could be impacted by training restrictions, personnel health, and safety due to increased temperatures, training range restrictions from environmentally degraded ranges, increased maintenance from environmentally stressed equipment, and infrastructure vulnerabilities to extreme weather effects. From the external perspective, it is surmised that the operational environment will change because of changes in conflicts (numbers and types) and increased demand for humanitarian assistance as well as additional factors such as economic impacts, environmental degradation of critical infrastructure and force protection staging areas, and access and availability to critical resources. In addition to the national security impacts on resources, infrastructure, and geopolitical factors, climate change can also impact economic stability and growth as a result of the costs from damages and recovering. For example, weather disasters with damages exceeding $1 billion have hit the United States each year since 1980 (EOS, 2014). According to the United Nations, on average more than 200 million people have been affected every year by disasters since 1991, the majority of these being weather related (United Nations, 2005)

The timescales of extreme weather events and global climate change are very different and can have different implications from a national security planning perspective. Extreme weather events occur over short timescales (days), whereas climate change gradually evolves over years to decades. From an analytical standpoint, the ground rules and assumptions can change, making it difficult to come up with quantitative assessments with a high degree of certainty. The impacts from both types of perturbations can also involve different timescales, ranging from a few years, for extreme weather events, to generational or centuries, for climate change.

Historical Perspective of the Role of Climate Change in National Security

Studies of climate change and the role of human factors in such changes have been performed for well over 150 years, including both numerous US National Academy of Science (NAS) studies and the United Nation's Intergovernmental Panel on Climate Change (IPCC) studies. The IPCC has conducted an assessment of the state of climate science and the potential impacts on climate factors every six years; in October 2013 they published their draft of the fifth assessment. In the draft report from the first of three working groups generating the full set of reports, the team of IPCC scientists reported with a 95 percent level of confidence that humans have been the largest contributing factor to global warming since the 1950s (IPCC 2013). Table 1 gives the high-level meteorological assessments from the 2007 IPCC report (IPCC, 2007a).

On March 31, 2014, the IPCC released the draft of Climate Change 2014: Impacts, Adaption and Vulnerability (IPCC, 2014) This report addresses a wide range of impacts due to climate change. Each assessment finding is rated based on the quality and quantity of available evidence, the agreement among the evidence, and, when appropriate, the degree of confidence that a given outcome has occurred or will occur in the future. However, analy-

Table 1. Summary of the high-level phenomenological assessments from the 2007 IPCC Report.

Phenomenon and direction of trend	Assessment of the likelihood of occurrence
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights.	Virtually certain
Warm spells/heat waves. Frequency increases over most land areas.	Very likely
Heavy precipitation events. Frequency increases over most areas.	Very likely
Area affected by drought increases.	Likely
Intense tropical cyclone activity increases.	Likely
Increased incidence of extreme high sea level (excluding tsunamis).	Likely

ses of these impacts as they relate to global factors and US national security interests have only been conducted relatively recently. Table 2 gives a high-level summary of some of the major assessments of climate change from a national security perspective.

National Security Impacts of Climate Change

The US DoD has considered the national security impacts of climate change from both internal and external perspectives. From the internal perspective, it has been surmised that the preparedness of US military forces could be impacted by training restrictions, personnel health and safety due to increased temperatures, training range restrictions from environmentally degraded ranges, increased maintenance from environmentally stressed equipment, and infrastructure vulnerabilities to extreme weather effects.

From an external perspective, climate change is often considered a driver for large-scale migrations. In one set of climate predictions made in the mid-2000 timeframe, it was postulated that northern Europe could become largely inhabitable as a result of the breakdown of the Gulfstream (the *Day After Tomorrow* movie scenario) and would result in massive migrations from northern to southern Europe. The historical record is not clear if climate change would be the decisive factor in triggering a mass migration, but it may be a contributing factor.

Migrations, voluntary and involuntary, have occurred throughout human history in response to many factors, including changing economic, political, cultural, and environmental conditions. Migrations are not necessarily a national security issue, but the NAS study identified involuntary "disruptive" migrations as those involving groups that are socially, politically, or economically disadvantaged in terms of their areas of origin, their final destinations, and/or the sensitive border areas they live in and must pass through. Environmental conditions, including extreme weather events and climate change, have driven and will continue to drive changes in migration patterns. Such migrations (IPCC, 2014), although disruptive, can provide an adaptation mechanism for changing environmental conditions.

Modeling the National Security Impacts of Climate Change and Extreme Events

As with many other domains, assessing the impacts from climate change and extreme weather events involves making vulnerability assessments of what could happen and using these assessments to develop potential response, recovery, and mitigation plans. After specific events occur, susceptibility assessments of the impacted areas would be made to develop actionable response, recovery, and mitigations activities. These processes are conceptually represented in Figure 1. The response and recovery plans and activities noted in Figure 1 generally relate to the immediate humanitarian and emergency response issues following an event, but within the context of this article are also intended to include addressing any national security issues or vulnerabilities that have been exposed by the event.

Figure 2 provides a representation of how the national security impacts of climate change and extreme weather events can be assessed. The main box on the left contains all of the initial and "pre-existing" conditions. These conditions include details on the underlying natural environmental factors (e.g., terrain and water), background weather, physical infrastructure, socioeconomic and political factors, and the human and cultural landscape. This last box involves the human players and actors that are

Table 2. A high-level summary of major studies examining the impact of climate change on national security.

Date	Organization	Major conclusions
1974	Central Intelligence Agency (CIA, 1974)	The pressure for food resources would continue to be a major factor in the developing world. Shifts could occur in food production areas around the world with a potential net effect being that the United States could become an even larger source of grain on the world stage and be subjected to increased global conflicts as a hungry world contests over reduced grain supplies
2007	Center for Naval Analysis (CAN, 2007)	Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world, and it presents national security challenges for the United States.
2008	National Intelligence Council (NIC, 2008)	In their fourth report of "Global Trends," the NIC identified climate change as national security factor.
2012	Department of Defense	Published a "FY 2012 Climate Change Adaptation Roadmap" that required DoD agencies to take climate change risks, as defined in the Quadrennial Defense Review, into account in both short- and long-term planning activities.
2012	National Academy of Sciences (Steinbruner et. al., 2012)	Consideration of the impacts of climate change and extreme events must be conducted at a whole-of-government level, not just at a DoD or single agency level.

impacted or must act on any postulated events and the cultural factors that may shape their responses and actions. The vast majority of analyses that have been performed to date have ignored these factors.

As Figure 2 notes, the box of the pre-existing conditions can also include the results from predefined vulnerability assessments. In this way, when actual events occur, the results from those vulnerability assessments can be used to shape the development of specific response, recovery, and mitigation actions.

It is important to note that the basic planning approach to dealing with climate change and extreme weather events is the same as planning for any perturbative event. There are some unique analytical issues, however, of dealing with climate change impacts.

Analytical Issue of Climate Change Impact Studies

In considering the impacts of climate change, one must consider that the impacts can come from abrupt, short-term extreme weather events (e.g., a "50-year" tropical storm) and from more gradual, long-term changes (e.g., sea level rises or shifting temperature patterns). Whereas these latter effects may provide more time to plan for, it may be more difficult to decide to prepare for them because the perception of the reality of the changes may be more difficult to see and agree upon. It is an unfortunate reality of the world that political leaders are reluctant to make potentially costly decisions about consequences that could occur decades into the future.

The modeling of the impacts of extreme weather events would not require any changes in the analytical concepts typically used in national security studies because it represents just another form of a typical "what if" study. In these studies, you postulate a set of perturbative conditions against an assumed set of static background conditions.

In analyzing the impacts of the gradual changes resulting from climate change, the background state of the environment becomes a dynamic aspect of the overall system. The background conditions will change, albeit slowly, such that the nature of the question asked may change from what is needed to be resilient against an extreme event to "when will formally considered extreme events become more common?" This is conceptually represented in Figure 3.

A change in the climate will be manifested as gradual changes in the sea level and mean air temperatures.[a] These gradual changes can alter the background weather patterns,

which in turn can give rise to extreme weather events that differ in location, frequency, and intensity. In other words, the gradual climate changes will result in two changes to the overall system over time—a change in the background conditions and a change the perturbative extreme weather events. Both types of changes must be considered in analyzing resiliency to future extreme weather events in a changed climate. Studies usually consider a range of extreme weather events but often do not include a range of background weather conditions. As an example of the latter, consider the greater New York area, which enhanced its infrastructure to make it less vulnerable to extreme weather events based on nonclimate enhanced conditions. Suppose that the infrastructure was designed to handle a storm surge of X feet above the baseline sea level. If there is a climate-induced change in sea level of ΔX, then a storm surge of only X – ΔX will cause the same damage as the storm surge of X feet for pre-climate-change conditions. Although this effect may seem abstruse or merely theoretical, in fact the assessment of storm surges for hurricanes takes into account the tides, which alter sea level along coastlines.

The impacts of these background changes (or changes in pre-existing conditions) are already being felt in some areas around the world. For example, areas around Norfolk, Virginia, are already experiencing routine flooding resulting from sea-level encroachment in low-lying areas. This is impacting both the city of Norfolk and the Naval Station at Norfolk. In the city of Norfolk, an ordinance has been passed requiring that all new and renovated buildings be elevated 3 feet above the flood plain, 2 feet higher than the previous requirement. In addition, a recent US Army Corps of Engineering (USACE) study (Li et. al., 2012) concluded that the major infrastructure at Naval Station Norfolk will not survive the anticipated storms and flooding expected later this century.

The USACE study used a near-shore hydrodynamic and sediment model to simulate potential future storms under five sea-level-rise scenarios (0.0, 0.5, 1.0, 1.5, and 2.0 m above the baseline or current sea level) and three extreme storm conditions (50- and 100-year return tropical storms, and a winter storm). They considered the impact of waves, tides, and storm surges. They used a suite of models, the Coastal Modeling System, which included a three-dimensional (3D) hydrodynamic model of the water as well as sediment transport and morphological changes in channels and coastal seabeds. They used a detailed topographic representation of the Norfolk area to assess the degree of inundation by the water. Even

Figure 1. Conceptual representation of how vulnerability assessments are used to support susceptibility assessments to develop actionable activities.

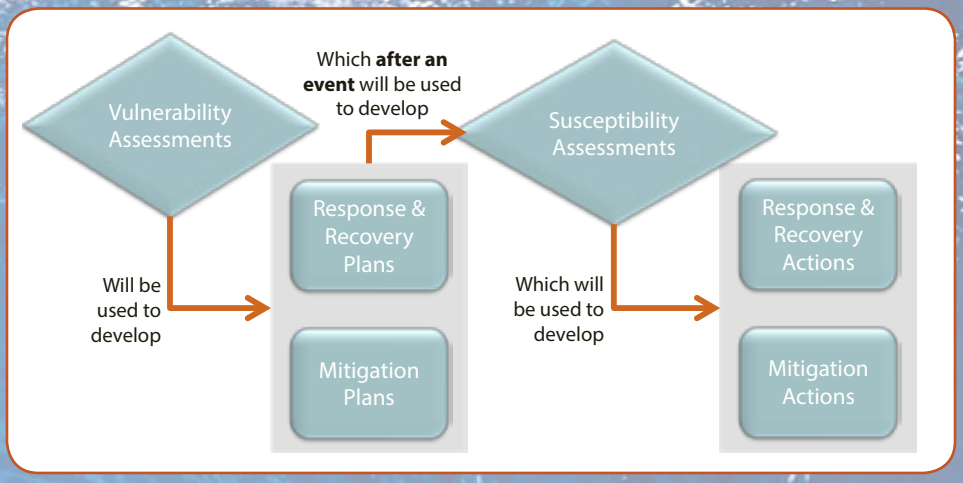


Figure 2. Model for assessing national security impacts from susceptibility assessments of climate change and extreme weather events.

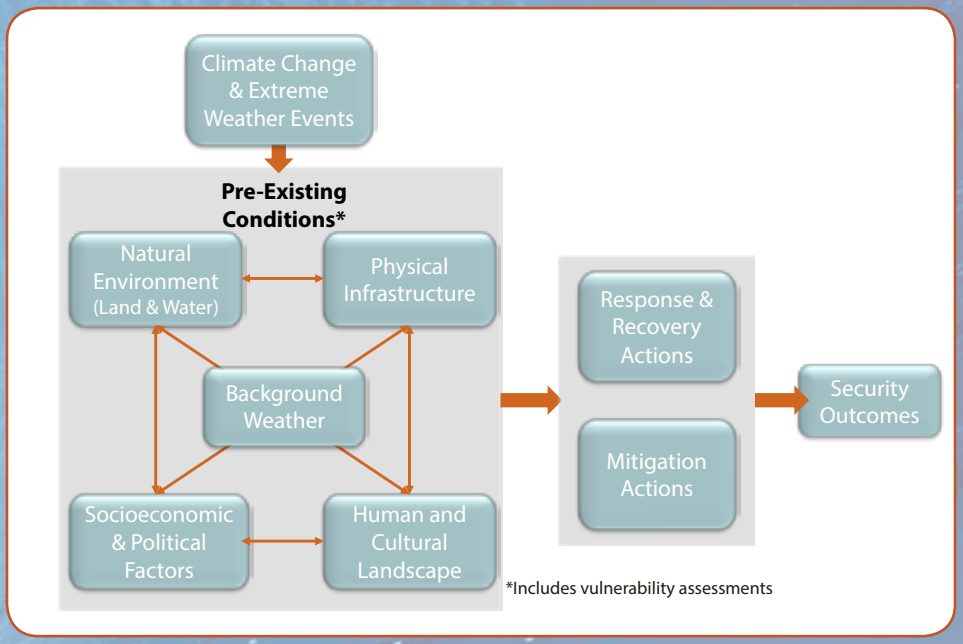
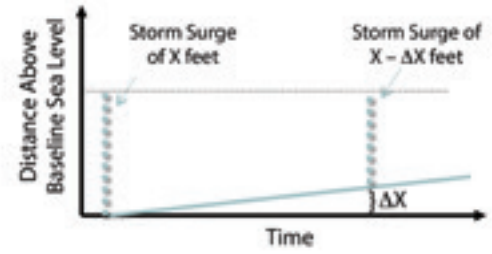


Figure 3. Notional representation of how smaller storm surges can equal the impact of larger storm surges in an enhanced sea-level environment.



under present conditions, Naval Station Norfolk would face flooding of approximately 8, 63, and 11 percent of the area under the three storm conditions (50- and 100-year tropical storm and a "Nor'easter" winter storm). Under a 0.5-m sea-level rise, the areas flooded by the storm conditions increase to 19, 70, and 26 percent, respectively. Under the most extreme condition of 2.0 m of sea-level rise, the areas flooded would cover 69, 78, and 73 percent of the station area under the three storm conditions. The Army study concluded that following a sea-level rise of 1.5 to 3 feet, the naval station and much of the Hampton Roads area would be under water for hours or days following a large storm. Because the naval station is dependent upon civilian infrastructure outside of the base, impacts in the surrounding area would affect base operations as well.

Results of the USACE study lead to an important point: environmental impacts from climate change will not differentiate between military and civilian infrastructures. Seeing that there are strong couplings between these infrastructure elements, a larger system-of-systems approach will be necessary to analyze the strategies to assess the impacts of climate change.

Need for Mitigation Strategies

Mitigation strategies will have to assess the environmental processes that are at the heart of the vulnerability. This will require knowing not only the assumed environmental background states, but also the nature and frequency of the anticipated extreme events. The modeling resources required will most likely involve very detailed, 3D physics models and high-performance computing resources. The technological assessments would examine the various technological solutions that could be used to provide the mitigation. Finally, the analyses would have to involve the various social aspects of the proposed solution, including cost, regulatory impacts, political considerations, the demographics of the impacted populations, and the potential disruptions to day-to-day life. As recommended in the findings of the 2012 NAS study, these assessments will require a whole-of-government solution.

The framing of the background assumptions may also have to change to consider the fact that under different sea-level-rise conditions, other baseline conditions such as topography of the study area may also evolve. The USACE study assumed that the basic topological conditions of the study area did not change under the assumed sea-level-rise scenarios. Because the average elevation above sea level was on the order of 2 m, this was not an unreasonable assumption, but it may not be valid in all cases. This would mean that the mitigation assessments may also need to consider changes in the base topography of the study either as a result of natural environmental processes or as a result of the introduction of protective features.

Answering these questions will be highly charged politically and will involve looking at timeframes that extend far beyond the usual timeframes of political decision makers The decision processes may also have to involve extremely unpopular decisions regarding areas for which mitigation solutions are not possible

Summary and Conclusions

Recent extreme weather events together with climate change, no matter what the forcing mechanisms are, can have national and international impact, with far-reaching implications. Indications are that occurrences of extreme weather events along with large-scale climate changes are becoming more common and must be accounted for in national security analyses. The impacts of climate change are much broader in scale and include additional factors such as economic impacts, environmental degradation of critical infrastructure and force protection staging areas, access and availability to critical resources, and stress on humanitarian resources. The timescales of these events are very different and can have very different implications from a national security planning perspective.

From an operations research perspective, two types of assessments will be required. The first involves vulnerability assessments of critical resources (facilities, equipment, and personnel) from extreme weather events and longer-term factors, such as sea-level rise. These analyses would utilize a variety of tools that are used in day-to-day planning. The second type of assessment would involve long-term assessments of the social, economic, and geopolitical impacts from climate change. These assessments will require a combination of historical evaluations as well as subjective assessments from a broad set of subject matter domains. Finally, with the im-

pacts of climate change being global, the assessments should be done as whole-of-government assessments because the implementation of mitigation strategies will require difficult prioritizing of resources.

Acknowledgements

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Notes

[a] The two most commonly cited indicators of long-term climate change are sea-level rise and increasing mean air temperatures, leaving many to assume that interior regions will not be impacted as soon or as significantly as coastal regions. The USACE study (Lozar et. al., 2011) titled Anticipating Climate Change Impacts on Army Installations, examines a different set of climate change factors—mean air temperature, changing precipitation patterns, erosion, and the resulting ecosystem changes—as they impact Army training installations in the continental United States (CONUS). The installations were rank ordered in terms of those most likely to experience significant impacts due to climate change. Of the top six installations, four are in the Midwest (Kentucky, Tennessee, and Arkansas) and two are in southern states (Georgia and Alabama).

MORS Heritage Pages 1996–1999

As we continue the countdown to the 50th Anniversary of MORS, we would like to revisit our proud history and highlight the past leaders of the Society and key accomplishments over those years. Each edition of *Phalanx* will provide insight into several years of history. Enjoy reading about these individuals and what they have accomplished. More information on the Past Presidents (PP) can be found on the MORS website, including their oral histories.

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Editor, Military Operations Research (MOR) Journal

Significant Events

65th MORS Symposium, Marine Corps University, Quantico, Virginia, June 10–12, 1997. *Analysis for Complex, Uncertain Times.* Dr. Paul K. Davis received the Wanner Award.

66th MORS Symposium, US Naval Postgraduate School, Monterey, California, June 23–25, 1998. *Preparing for Military Operations Research in the 21st Century.* Larry D. Welch received the Wanner Award.

67th MORS Symposium, US Military Academy, West Point, New York, June 22–24, 1999. *Focusing Military Operations Research: From Our Heritage to the Future.* Dr. Donald B. Rice received the Wanner Award.

1997: The following individuals were inducted as Fellows of the Society: Dr. Jack Borsting, FS; Dr. Gregory Parnell, FS; and Dr. David Schrady, FS.

1997: MORS Board of Directors established a new Executive Council position—President-Elect.

1997: First MORS Symposium (MORSS) hosted by the USMC in Quantico, Virginia.

1998: The following individuals were inducted as Fellows of the Society: Vernon Bettencourt, Jr., FS; Christine Fossett, FS; and Dr. Jacqueline Henningsen, FS.

1998: MORS republished the first in its series of "classic" books that have documented and influenced the development of the military operations research profession, *Methods of Operations Research,* written by Morse and Kimball. The purpose of this MORS series was to keep military operations research relevant.

1998: The MORS Board approved two new awards: the Clayton J. Thomas Award, to recognize outstanding individuals for consistent, sustained technical contributions to improve the analytical underpinning of the military operations research profession; and the John K. Walker Jr. Award, to recognize the author of the technical article judged to be the best published in the *Phalanx* during the previous calendar year.

1999: The following individuals were inducted as Fellows of the Society: Brian McEnany, FS; Dr. Stuart Starr, FS; and Dr. Harry Thie, FS.

1999: Dr. Robert L. Helmbold was the first Thomas Award Laureate.

1999: Dr. Jerome Bracken and Richard E. Darilek were the first Walker Award Laureates.

1997–1999: The MORS Elected Board of Directors changed the bylaws to make the Executive Vice President a voting member of the board.

MORS Presidents

31st MORS President: Fred Hartman, 1996–1997

Fred Hartman was elected MORS President in 1996 and had the honor of presiding over the first MORS Symposium hosted by the US Marine Corps in Quantico, Virginia, in June 1997. He was elected a Fellow of the Society in 2000.

Mr. Hartman graduated from the US Military Academy with a BS in engineering and served as a field artillery officer and army aviator in Viet Nam. After receiving an MS in operations research from the Naval Postgraduate School, Fred completed several Army analytic assignments prior to leaving active duty for an industry career.

Mr. Hartman joined CACI in 1981 and over the next 10 years progressively moved from department manager to executive vice president. In 1992, Mr. Hartman became chief operating officer, cofounder, and member of the board of directors for Applied Solutions International, a technology startup offering consulting services for defense industries and international trade, including work for the United Nations Development Programme, Army Research Labs, and the Small Business Innovation Research Program (SBIR).

Mr. Hartman joined IDA in 1996 as a training modeling and simulation advisor to the Department of the Under Secretary of Defense (DUSD) (Readiness) and served from 2000 to 2003 as Technical Director, Joint Simulation System, and Manager, Enterprise Division of the Defense Modeling and Simulation Office. In 2003, Fred joined the Office of the DUSD (Personnel and Readiness) as Director, Training Transformation Joint Assessment and Enabling Capability, and as Deputy Director, Readiness and Training Policy and Programs, returning to IDA in 2007.

Mr. Hartman is currently an analyst on the research staff of the Institute for Defense Analyses, and has an extensive background in models, simulations, and training applications, with defense-related management and analysis positions in both industry and government. He has specialized in problem solving with the use of models and simulations, assessing training systems and technical applications for more than 35 years. Mr. Hartman continues to support the Department of Defense with strategic planning for modeling, training, and acquisition projects. In addition to leadership positions in modeling and simulation professional organizations, Mr. Hartman has served as a member of the Army Science Board, and led a study panel for the National Academy of Sciences, Board on Army Science and Technology.

32nd MORS President: Jerry Kotchka, 1997–1998

Dr. Jerry Kotchka served as program chair of the 63rd MORS Symposium and then Vice President for Finance and Management in 1996–1997. He was elected President of MORS from 1997–1998 and Fellow of the Society in 2002.

Dr. Kotchka graduated from the US Naval Academy with a BS in general engineering in 1962. He received his MS in operations research from the US Naval Postgraduate School in 1967, and a PhD in operations analysis from the Ohio State University in 1970. As a Federal Executive Fellow at the Brookings Institution in 1974, he contributed to their report, *Setting National Priorities: The 1975 Budget.*

Dr. Kotchka is a retired Captain in the US Navy with more than 26 years of service. His naval career was divided between sea duty and analysis positions including the Office of the Chief of Naval Operations (Systems Analysis Division), OSD Program Analysis and Evaluation (Naval Forces Division), and the Naval Center for Cost Analysis.

In 1988, Dr. Kotchka joined the McDonnell Douglas Corporate Office as Director of Advanced Systems Analysis, providing oversight to the corporation's multiple companies' operations analysis teams. He then joined the McDonnell Douglas Missile Systems Company as Director, Cost and Operational Effectiveness Analysis Joint Direct Attack Munitions Program, which the company won and is in production and used today. Dr. Kotchka then managed Boeing Phantom Works programs with the intelligence community and used operations analysis techniques to successfully demonstrate the effectiveness of the intelligence community efforts to their customers. In 2000, he retired from the Boeing Company and joined Lockheed Martin Missile Systems Company as Director of Operations Analysis. In 2005, two years after the company relocated him to the Virginia Beach area, Dr. Kotchka retired in the same area where he began his professional career in 1962.

Since retirement, Jerry has supported the MORS Educational and Professional Development Colloquium and advised MORS leadership.

33rd MORS President: Dennis Baer, 1998–1999

Mr. Dennis Baer served as Vice President for Professional Affairs in 1996–1997 and Vice President for Financial Management in 1997–1998, before being elected President in 1998. He was elected Fellow of the Society in 2005.

He received his BS in mathematics from the Ohio State University in 1977 and an MS in operations research from the Naval Postgraduate School in 1988.

Mr. Baer served as a naval aviator and retired as Commander after 20 years of service. He joined Northrop Grumman in 1997, where he was Manager of Navy Programs and Economic Resource Analysis. His portfolio included numerous Navy modeling and simulation programs and cost analysis support to various Department of Defense programs and studies. After eight years, he joined Whitney, Bradley, and Brown, where he was Manager, Operations Analysis and Assessments. His primary duties included both effectiveness and cost analysis support to various analyses of alternatives and studies. Mr. Baer was later promoted to Director, Business Development Opeations and Deputy Capture/Proposal Management. He was responsible for training, processes, and mentoring of capture and proposal efforts across the entire corporation, management of the corporate business development pipeline, corporate development strategic plan, and corporate development board.

He is currently the Naval Aviation/USMC Branch Head at the Naval Center for Cost Analysis, where he is responsible for independent cost estimates and assessments of major acquisition programs.

He has remained active in MORS as the Mentorship Coordinator and recently chaired the Industry and Institution Relations Committee.

MORS' Young Analysts
The Next Generation of Leaders

The future of operations research and the national security community depends on new analysts taking the helm. MORS' Young Analyst Initiative facilitates this process by providing paths for emerging analysts to engage with MORS through publishing, meeting participation, volunteering, mentorship and recognition.

To highlight the achievements, interests and aspirations of young analysts, we turn the spotlight on one deserving individual in every issue of *Phalanx*.

To learn more about the Young Analyst Initiative, connect with other young analysts, see past featured analysts and learn how you can nominate a deserving analyst, please visit

WWW.MORS.ORG/YA

Capt David F. Wade

When did you join MORS?

I've been actively working with MORS since 2011. I became an official member this year.

What was your childhood ambition?

When I was a child, I enjoyed building things and always wanted to be an architect. I would like to think that being an operations research analyst I haven't diverted too far from that aspiration.

Why did you become an operations analyst?

I studied mathematics in undergrad, so naturally when commissioning in the Air Force I was assigned the job of operations research analyst. Coming into my first job working as a personnel policy analyst at Headquarters in Washington, DC, I didn't have the first clue of what operations research was or what an operations research analyst did. I quickly learned the ropes and the nature of what an operations research analyst does and fully embraced everything it entails.

Where do you see yourself in five years?

I am currently a master's student at the Air Force Institute of Technology in Wright Patterson AFB, Ohio, pursuing a systems engineering degree with a focus in industrial engineering. In five years, I hope to use this experience to move more into project and program management.

How has your MORS membership benefited you? What do you value most about your membership?

My MORS membership and involvement has benefited me the most in learning what other young analyst have been working on in their fields, and using their experiences as an influence and inspiration for my own. Before joining MORS, I was unaware of how important networking within the field was, especially outside of the military. It has helped me gain a whole new perspective and a new appreciation for the field of operations research.

A TRIBUTE TO

Edward P. Keller, Jr., LTC (ret.),

June 23, 1938–February 15, 2014

Jim Bexfield, FS, jim_bexfield@comcast.net
Philip Major, IDA, pmajor@ida.org; and Bob Sheldon, FS, bs@group-w-inc.com

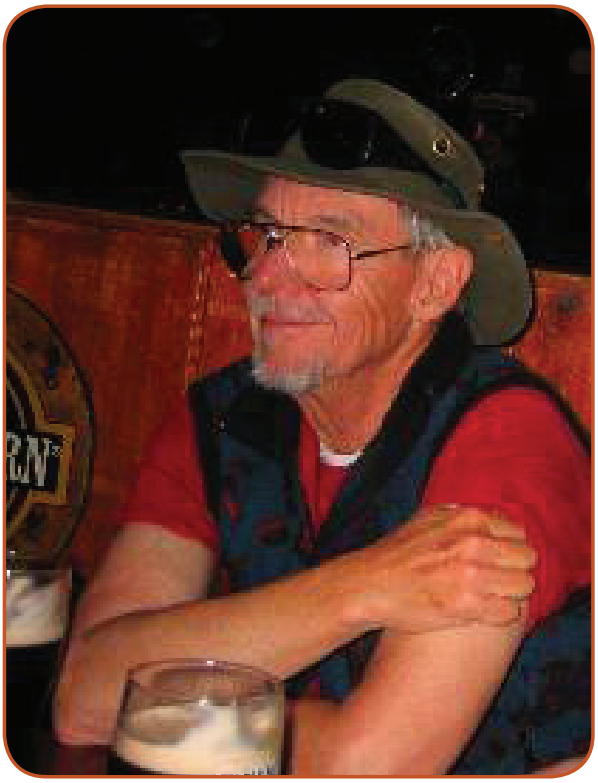
Edward P. Keller, Jr., LTC (ret.) was a member of the MORS Board of Directors from 1981 to 1984. During that time, he was the first Director of the Army Training and Doctrine Command (TRADOC) Element Monterey (May 1980–February 1983) at the Naval Postgraduate School (NPS). Prior to that, Ed served as an Army Air Defense Artillery Officer selected to attend NPS. He received his MS (with distinction) in operations research in 1977. He remained at NPS, taught, and built the model STAR with Sam Parry until his retirement in 1983.

While at NPS, Ed was the site coordinator for MORSS in December 1981. He set the standard for site coordinators from then on. He was always ready to help MORS.

In 1983, Ed joined Rolands & Associates Corporation, where he was instrumental in the development of the Ground Combat, Logistics, and Special Forces representation in the Joint Theater Level Simulation (JTLS). According to his previous employer, "JTLS would not be JTLS without Ed's guidance and ideas."

Ed started working part-time in 2007 but never fully retired, providing insightful advice through 2013.

He spent time with his family and pursued a wide variety of interests. He was a lover of Irish heritage and music, a dog lover, an avid fly fisherman, and a Boy Scout leader.



He traveled the world in search of the best fly fishing. One of his favorite spots was close to home at Pyramid Lake, where he enthusiastically ladder fished! He was an active fundraiser for Project Healing Waters, an organization dedicated to the rehabilitation of disabled military personnel through fly fishing and associated activities. Just two months ago, he outfished his sons and friends on a Northern California river. Sadly, it was the to be the last steelhead he ever caught.

He was diagnosed with prostate cancer in 2006 and a brain tumor in late 2013. He fought bravely to regain his health, but it was not to be. On the evening of February 13, he sat with his family on his front porch watching the light reflecting off Monterey Bay. Ed always loved the view, which reminded him of his childhood watching similar lights on Hingham Harbor. On February 15, he died peacefully at home with his children at his side.

Fellow MORSian, Jim Bexfield, FS, remembers Ed as one of his biggest supporters and contributors during the first year of his presidency. He was always easy to find at the Directors' dinner—just look for the red blazer.

Another fellow MORSian, Wayne Hughes, said "Ed was a grand citizen of our country in peace and war."

He will be sorely missed.

PuzzLOR

Spy Catcher

Your government has lost track of a high profile foreign spy in South America and they have requested your help to track him down. As part of his attempts to evade capture, he has employed a simple strategy. Each day the spy moves from the country that he is currently in to a neighboring country. (See http://puzzlor.com/2014-04_SpyCatcher.html)

The spy cannot skip over a country (for example, he cannot go from Chile to Ecuador in one day). The movement probabilities are equally distributed amongst the neighboring countries. For example, if the spy is currently in Ecuador, there is a 50% chance he will move to Colombia and a 50% chance he will move to Peru. The spy was last seen in Chile and will only move about countries that are in South America. He has been moving about the countries for several weeks.

Question: Which country is the spy most likely hiding in and how likely is it that he is there?

Send your answer to puzzlor@gmail.com by June 15, 2014. The winner, chosen randomly from correct answers, will receive a $25 Amazon Gift Card. Past questions can be found at puzzlor.com.

PuzzLOR is the creation of John Toczek. John is the Sr. Director of Decision Support and Analytics for ARAMARK Corporation in the Global Operational Excellence group. He earned his BSc. in chemical engineering at Drexel University (1996) and his MSc. in operations research from Virginia Commonwealth University (2005).

Pseudo Analytical Agenda

Another Four Years Another QDR

P. Cicada

"Morning, Bill," said Pete.

"Morning, Pete," said Joe.

"Morning, Joe," said Bob.

"Another QDR due," said Bill.

"Yep," said Pete. "Everyone clocked in?"

"Yep," replied Joe, Bob, and Bill.

"Let's write about the world," said Bill.

"Rapidly changing," said Pete.

"More dynamic and unpredictable," said Joe.

"More dangerous and more contested," said Bob.

"Even more than 1939?" asked Bill.

Pete, Joe, and Bob stared at him.

"OK," said Bill. "Rapidly changing, more dynamic and unpredictable, more dangerous, and more contested. Write those down."

They all wrote.

"What's our strategy?" asked Pete.

"Protect ourselves," said Joe.

"Protect our friends," said Bob.

"Kick their butts if they mess with us or our friends," said Bill.

"Do we put in the stuff about dissuade, deter, cooperate, mitigate?" asked Bill.

"Yep," replied Pete, Joe, and Bob.

"Okay," said Bill. "Write that down."

They all wrote.

"How are we going to do this?" asked Joe.

"New paradigms," said Bob.

"Maximize effects while minimizing costs," said Bill.

"Coordinate with allies and partners," said Pete.

"Ok," said Joe. "Write that down."

They all wrote.

"Should we rebalance?" asked Bob.

"We should go West," said Bill.

"I say East," said Pete.

"If you go far enough West, then it's just like East," said Joe.

"Okay, it's 60 percent West," said Bob. "Write that down."

They all wrote.

"What about a force-sizing construct?" asked Bill.

"Two major wars plus the homeland," said Pete.

"One major war plus one minor war plus the homeland," said Joe.

"Simultaneously defending the homeland; conducting sustained, distributed counterterrorist operations; and in multiple regions, deterring aggression and assuring allies through forward presence and engagement. If deterrence fails at any given time, US forces will be capable of defeating a regional adversary in a large-scale multiphased campaign, and denying the objectives of—or imposing unacceptable costs on—a second aggressor in another

region," said Bob.

Bill, Pete, and Joe stared at him.

"Wow," said Pete.

"Okay, I guess," said Bill. "Write that down."

They all wrote.

"What about the force?" asked Pete.

"More pay," said Joe.

"They gave us more pay," said Bob.

"Maintaining our commitment to sustaining and strengthening the health of the All-Volunteer Force in times of decreasing defense budgets requires us to make prudent, significant, and enduring reforms wherever possible. This includes finding efficiencies within the Department of Defense organization, reforming our internal processes and consolidating our infrastructure, and making some adjustments to pay and compensation. In doing so, we will exercise good stewardship over the resources entrusted to the Department of Defense while continuing to honor the sacrifices of all those who serve," said Bill.

Pete, Joe, and Bob stared at him.

"Does that mean more pay?" said Joe.

"We'll decide tomorrow," said Pete. "Good night, Joe."

"Good night, Bob," said Joe.

"Good night, Bill," said Bob.

Member Milestones

LtCol Kira Therrien retired from the Air Force on May 29. She has accepted a position as a program manager for Empirical Testing Corps in Colorado Springs. Best of luck in your new career, Kira!

MORS President-Elect, Dr. Rafael E. Matos, was invited to be guest lecturer of the Mathematics Department of the Indiana University of Pennsylvania (IUP), in Indiana, Pennsylvania, on February 21 as part of the INFORMS Speakers Program. Dr. Matos presented lectures spanning topics from the use of OR and statistical methods in military analysis to career advice for new analysts. The INFORMS Speakers Program is designed to provide students and faculty access to recognized experts in operations research, analytics, and the management sciences.

Rafael E. Matos

Dr. John Hummel has been named the director of the new Center for Integrated Resiliency Studies at the US Department of Energy's Argonne National Laboratory. Resiliency involves linked contributions from all aspects that make up a community—physical infrastructure, socioeconomic elements, and environment. The new center will draw together expertise from across the lab to develop planning tools for local and federal decision makers to reduce vulnerabilities in physical and social infrastructures, as well as develop mitigation and recovery plans that can speed recovery times after events. The establishment of the center is a direct outgrowth of a MORS special meeting on the topic of resiliency held at the lab last year.

Dr. John Hummel

New job, new project, or just something your colleagues should know about? Submit your milestones to phalanx@mors.org.

The Last Word

Thoughts on the Education of Military Operations Research Analysts

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From my perspective as a practicing military operations research analyst who has transitioned to a second career as an educator, I have had the opportunity, and indeed the privilege, to participate in the education and development of many analysts over the last 25 years or so. Quite a few of these analysts have become leaders in the field and have successfully supported decision making at the highest levels. But despite the many success stories, the process of preparing an analyst for productive work on a continuous and long-term basis is a difficult one that doesn't end when the classroom is left behind. So, although a solid academic foundation is very important, the process also involves gaining experience on the job, using more formal continuing education opportunities, and participating in the professional activities of the field. Each will be discussed below.

The leadership of MORS has long recognized the importance of the continued development of the military operations research workforce to enhance of the quality of analysis performed to support decision making. For the last several months, a committee of MORSians has been considering the various aspects of the education and professional development process. The goal of this effort is to improve the ability of MORS to contribute to the professional development of its members, and to align continuing education opportunities with the needs of the decision makers and the companies and agencies that perform defense analysis. A significant amount of work has been done, including a broad survey of the analytical community to determine specific gaps in the skillset of OR analysts. This is an important effort, and the findings and recommendations of the group should go a long way toward establishing the role of the Society in the education and professional development process. Although I have participated in the effort, this article represents my own thoughts and is independent of the work of the committee.

It is generally recognized that a master's degree in operations research or a related field such as applied math, industrial engineering, systems engineering, or statistics provides the basic knowledge and background for service as a defense analyst. E. B. Vandiver, former Director of the Center for Army Analysis and a personal mentor of mine, conducted a career counseling session for all new arrivals at CAA. Those who did not already possess a master's in OR were strongly advised to obtain one, and financial support was provided to the new analyst to facilitate his or her studies. He recognized that the level of analytic maturity that an analyst achieves through the pursuit of this sort of graduate study was essential, and made the analyst much more valuable to the agency. He also knew that a master's degree was necessary for the individual to

compete in the field, both inside and outside the government.

Operations research is all about gaining insight about a system through the choice or construction of a model. The assumption is that the behavior of the model will sufficiently mimic the behavior of the system so that these insights can be realized and will lead to improved decision making. So the focus of a graduate OR program is modeling in its many forms. Students learn to simulate, to optimize, to perform statistical analysis, to represent stochastic systems, and to do decision analyses. They are exposed to many classes of models. But modeling is a creative activity. The hope is that exposure to many classes of models will help the student develop the ability to construct the appropriate model for the problem at hand. The need for this level of creativity sets operations research apart from many other scientific disciplines. There is no easy way to teach it. Furthermore, students must understand that, as a creative activity, there may be multiple approaches that could be applied, and there is no absolute "right answer" regarding the choice of the modeling approach, and that reasonable people can disagree about what approach to take.

Most graduate OR programs include a synthesis activity in the form of a major project or a thesis. The goal of this work is to give the student the opportunity to put together all they have learned and apply it to a realistic problem. The best of these efforts involve interaction with a sponsor who really cares about the results. The students learn the difficulty of determining the real problem that needs to be solved, as they are forced to go back and forth with their sponsor to refine the definition of the problem. Often the problem requires them to learn new methods and techniques that were not covered explicitly in their classes. The confidence and ability to go beyond classroom-level work is a primary goal of the project or thesis because the problems they will encounter later will depend on this capability. They also have the opportunity to communicate their methodology and results, both in writing and orally. The communication skills needed to support decision making are considerable. In many cases analysts must explain their methodology and results to decision makers who have no idea of what they did or why, and do so in a credible and convincing manner. The opportunity to practice that skill in a more benign educational environment, before they have to exercise these skills with a real decision maker, is a huge benefit to the student.

Our goal as educators is to prepare students to function as analysts in the so-called "real world." But that preparation largely amounts to giving the student the ability to learn what they need to know to do their job. That learning takes place on the job, and in the best case, under the supervision of experienced practitioners that provide the guidance a new analyst needs. But different supervisors, and indeed different organizations, handle the development of their junior analysts in different ways. Analysts that are assigned to the large Army analysis agencies tend to start out at the bottom of the food chain and work their way up as they gain experience and capability. The Coast Guard sends their newly minted OR masters to individual staff sections alone. They must develop largely on their own once they graduate. Fortunately, there are many success stories across this spectrum. Young civilian analysts have the added disadvantage, in many cases, of having to learn about the various aspects of the military and how it works. In most cases, when an educator encounters a former student a year or two after graduation, the growth and development that the student exhibits is amazing, and there is no substitute for experience on the job. Still, organizations that invest time and other resources in the professional development of their employees maximize this effect and the positive results manifest themselves in the form of improved support to clients.

The development of analysts on the job can be augmented by participation in some of the many continuing education courses offered by various organizations and educational institutions. These courses are often of short duration and the student does not receive academic credit for them. Appropriately accredited organizations can award participating students Continuing Education Units (CEUs) that represent 10 hours of instruction. Records can be kept and transcripts documenting the courses that the students have taken can be provided. Some fields require documented continuing education of its practitioners, and this system of nonacademic credit serves the purpose of providing proof that the requirements have been met. So far our field has not implemented such requirements, but it is possible in the future that some sort of credentialing could be available to military OR analysts. In related fields, certification of practitioners has already started. The Institute for Operations Research and the Management Sciences (INFORMS) provides practitioners the opportunity to become Certified Analytics Professionals, and the International Council on Systems Engineering (INCOSE) provides a similar opportunity to become a Systems Engineering Professional. Years ago, in a discussion about the Verification, Validation, and Accreditation (VV&A)

process, a cynical friend of mine commented that models should not be accredited; rather, analysts who use models should be accredited. This is because all models are wrong to some extent, but good analysts can still gain insight through their use. Perhaps we are getting closer to the point of accrediting analysts.

The proliferation of online instruction has opened the door to a much more diverse offering of continuing education subjects than were available in the past, and there is no longer the need for students to gather in one place to receive the instruction. Also, classes can often be taken from people who are acknowledged experts on the subject of interest online when, previously, access to this level of instructor was much more limited. In many cases, continuing education courses of this nature are given without grades or tests or even homework. In my experience, to really learn a new methodology or technique, a student must be allowed—or even required—to do some sort of practical exercise or application. Watching PowerPoint slides go by describing new methods often gives students the false impression that they understand and could use in practice what is being discussed. So, the best of these courses will have some student exercises as part of the curriculum. Otherwise, the courses serve only to introduce a topic with the hope that the student can gain sufficient knowledge later, on their own, to be able to use the method in practice.

The need for continuing education and professional development is not limited to junior analysts. In our field, new and improved methods are available for use, and new problems and applications are constantly arising. Keeping abreast of the developments is very difficult. Also, the level of documentation of work has changed over the years. Early in my career, studies often involved a large number of people and they took a long time, often more than a year. At the conclusion of the work a study report that fully documented the effort was written. The report contained a complete description of the problem, all the data, explanation of the methodology, and all the results. The report was submitted to the Defense Technical Information Center (DTIC), and could easily be found later by others who were doing similar or related work. Lately, the emphasis has been on quick-turn analysis that is documented by a PowerPoint briefing that is much less complete. As a result, it is difficult to do the "research" part of operations research. Many analytical efforts are forced to start from scratch even though related work was done previously that could have provided a head start.

In my experience, the best way to keep current on developments in the field is through participation in the professional activities of the field, namely, the various symposia, workshops, and meetings of MORS, MAS, and to some extent, INFORMS. These are the places where an analyst can hear about and learn, not only about the innovative work that is being done, but who is doing it. The networking aspect of attendance at these events cannot be overemphasized. The ability to call someone that you met at a MORS Symposium to get help and advice transcends service affiliation and rank, and it facilitates doing the best analysis possible to support decision making. To those of us who have been involved in these activities over the years, the idea that essential learning and development takes place at MORS meetings is obvious. Even so, there has been resistance among some of the analytic leadership of the Department of Defense and the Department of Homeland Security to support these activities. This, in my view, is short sighted.

Our field is a moving train of methodology and problems. Only a commitment to lifelong learning will ensure the best possible support to the decision makers who are making potentially life-and-death decision that also involve the expenditure of massive amounts of tax money.

About the Author

Dr. Andrew Loerch is an associate professor and the associate chair of the Department of Systems Engineering and Operations Research at George Mason University, where he directs the track in Military Applications of Operations Research in the master's program in operations research. He holds a master of science degree in operations research from the Naval Postgraduate School, and a PhD in operations research from Cornell University. He is also a retired Army Colonel with 26 years of active federal service, of which 15 years was spent as a military operations research analyst. Dr. Loerch is a Past President and Fellow of the Military Operations Research Society, an associate editor of Military Operations Research, and is the editor of the book, Methods for Conducting Military Operational Analysis. He recently received the Vance R. Wanner Memorial Award for outstanding contributions to the field of defense analysis. He is an avid cyclist and senior softball player, the principle bassoonist of the Manassas Symphony Orchestra, and a diehard fan of the New York Yankees.